Sky and TELESCOPE

Wisconsin amateur and guests

In This Issue:

★

Vol. XVIII, No. 7

MAY, 1959

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The Spiral Structure of the Milky Way

Some Radio Telescopes — II

A Model of Jupiter's Satellite Orbits

American Astronomers Report

Radar Echoes from Venus

Some Astronomical Stamps — V

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Sky and TELESCOPE

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COVER: At his observatory in Appleton, Wisconsin, Jerome J. Knuljt is frequently host to observing groups, who make use of the several telescopes he has installed in a dome of unique design and construction. This troop of girl scouts is learning about the 8-inch reflector that was set up after completion of the observatory a few years ago; that instrument has since been replaced by a 10-inch. Photograph by Frank Weltman of the Appleton "Post-Crescent." (See page 406.)

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Minor Planet Survey

ALTHOUGH the first asteroid was found in 1801, and 1,616 of them had been numbered by the end of 1957, until recently there had been no systematic photographic survey for the determination of their brightnesses on a photometric scale.

In 1950, G. P. Kuiper and his coworkers at Yerkes and McDonald Observatories undertook such investigations to provide information for statistical analyses. All measures resulting from their work have now been published in *Astrophysical Journal* Supplement 32, including mean photographic magnitudes at opposition for all numbered asteroids.

Observations were made with a 10-inch Ross-Fecker telescope borrowed from the Cook Observatory. Between 1950 and 1952, the entire ecliptic was photographed nearly twice around to a width of 40 degrees, covering the zone of the sky where most asteroids would be found at their oppositions. The exposures were limited to 10 minutes to minimize asteroid trailing; thus, the limiting magnitude for these objects was generally 16 or 17.

On the 1,094 pairs of 8-by-10-inch plates, each covering 6.5 by 8.1 degrees, more than 3,000 asteroids were recognized. Of these, 26 per cent could not be identified with known objects. Six of the new minor planets were suspected to be Trojans, moving around the sun in orbits nearly coinciding with Jupiter's.

Asteroids found on each plate were measured for position, daily motion, and magnitude. The last quantity was determined in most cases by comparison with stars of known brightness in the Selected Areas, and the derived values have a ±0.15-magnitude probable error.

One of the principal aims of the survey was to determine the number of asteroids for each magnitude interval. It was necessary to find out how many catalogued asteroids had been missed in the survey, and how many were missed in the examination of one plate but found on an overlapping section of another. The results are summarized in the table, arranged by opposition magnitude.

Opp. Mag.	*Count 1957*	*Computed*	*Opp. Mag.*	*Count 1957*	*Computed*
7	2	1	14	269	332
8	1	3	15	478	740
9	3	6	16	401	1,660
10	9	13	17	133	3,700
11	30	30	18	12	8,300
12	83	66	19	7	18,600
13	185	148	20	3	42,000

The computed number of asteroids brighter than magnitude 19.5 is 33,600, in substantial agreement with the figure 55,000 based on a revision of W. Baade's earlier result obtained from rather limited data. Incompleteness in the counted number in the present survey probably starts at magnitude 14.

The Spiral Structure of the Milky Way

OTTO STRUVE, *Leuschner Observatory, University of California*

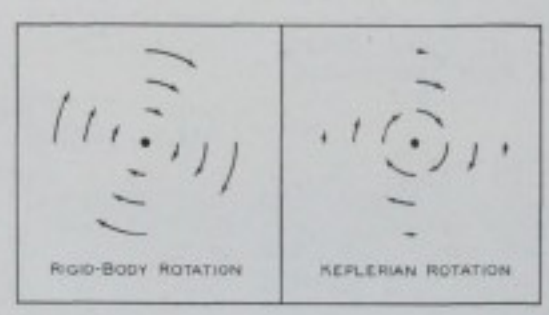
THE FIRST INDICATION that astronomers might be able to trace spiral arms in our galaxy came with W. Baade's discovery that the luminous *O* and *B* stars in the Andromeda galaxy, M31, lie along such arms. Shortly afterward, in 1951, W. W. Morgan and others investigated the distribution in distance of luminous early-type stars along the Milky Way, and the first vestiges of spiral arms became discernible.

In recent years evidence for the existence of these features in our galaxy has come from numerous sources. Optical observations are, however, limited by the all-prevailing haze of interstellar absorption in and near the galactic plane, whereas radio observations, which are unaffected by this obscuration, yield at present the clearest pattern.

But the entire picture of spiral structure in the Milky Way system depends upon the determination of distances from us to the various features, particularly those recorded as a function of wave length on tracings showing the intensity of the 21-centimeter emission line of neutral hydrogen. To transform the radial velocities obtained from the radio observations into distances, we must know how the circular velocity in our galaxy varies with the distance *R* from the galactic center.

A variety of optical observations indicates that the stars in the solar neighborhood are moving in the direction of Cygnus at about 220 kilometers per second, approximately the sun's circular velocity around the galactic center at a distance of some 8,200 parsecs (26,700 light-years). But what are the corresponding velocities at other distances from the center?

Let us consider two limiting cases. First, the galaxy may rotate as a rigid body, like a phonograph record. This would be true if the stars were uniformly distributed



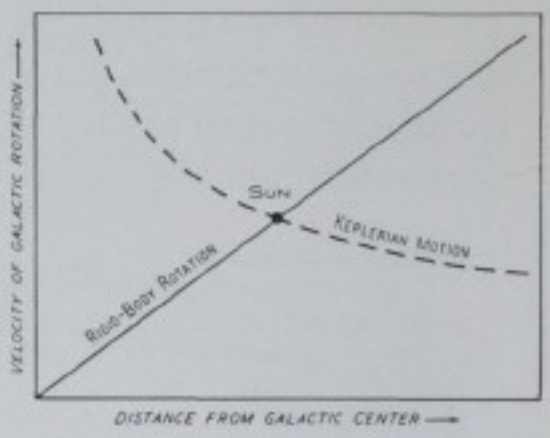
throughout the system (see my article on Henri Poincaré's work in the March, 1958, issue, page 226). Second, the individual stars might move at different speeds in accordance with Kepler's third law. This would apply if practically the entire mass of the galaxy were located at a central point, as is the case for the solar system.

One of our most powerful tools for measuring stellar motions is the spectroscope, as the Doppler shift of the lines in a star's spectrum is independent of its distance. For this shift depends only on that component of the motion that is in the line of sight, toward or away from us — the radial velocity. But if the galaxy in the sun's vicinity were in rigid-body rotation, the average radial velocities of both nearby and distant stars would be zero. This is because we measure stellar radial velocities with respect to that of another star — the sun — and because the distance between any two points in the galaxy would remain the same.

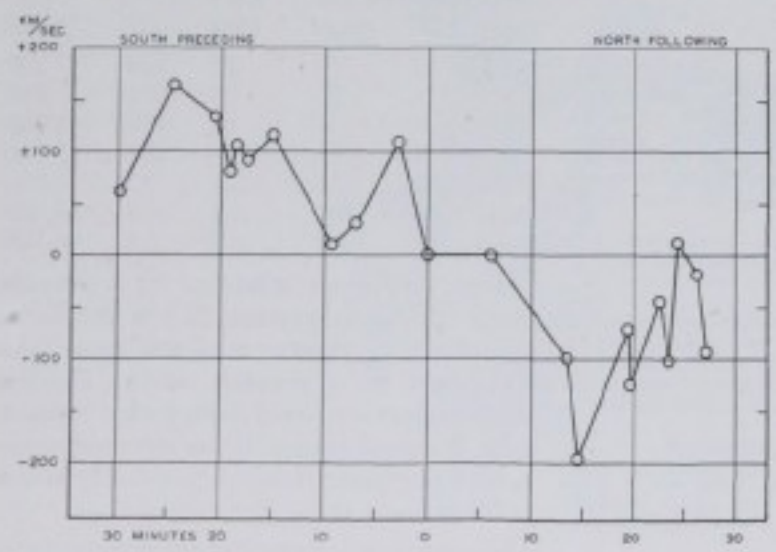
As for motions across the face of the sky — the proper motions — these would also tend to be zero, if we measured the stars with respect to one another. But rigid-body rotation would be indicated by the steady increase or decrease in the galactic longitude of a fixed direction, such as that of the vernal equinox, with respect to which the co-ordinates of all stars are determined.

The first evaluation of a systematic drift in star positions as a result of rigid-body rotation is usually attributed to L. Struve in 1887. From his analysis of the proper motions of stars in Bradley's catalogue, he deduced a shift of -0.41 ± 0.42 second of arc per century in galactic longitude. However, he mentioned in his paper that F. Bolte of Göttingen had obtained a similar result a few years earlier. According to P. P. Parenago, the modern value is -0.28 second of arc per century.

Rigid-body rotation requires that the rotational velocity at each point be directly proportional to its distance from the center of rotation. Hence, if we plot velocity as ordinate against distance from the center as abscissa we obtain a straight line, and the greatest velocities are at the greatest distances.



Our second limiting case is Keplerian motion, such as that of the members of the solar system. Kepler's third law states that the square of the period of revolution of one object around another is proportional to the cube of their average separation. In a circular orbit, the period equals the distance around the circumference ($2\pi R$) divided by the velocity. Combining these facts shows that the velocity is inversely proportional to the square root of the radius of the orbit. If we again plot distance versus velocity, the curve is



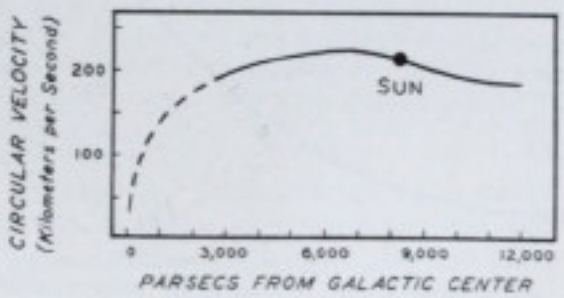
Arrows in this picture of M33 mark emission patches observed spectroscopically to get the galaxy's rotation curve at the left. After N. U. Mayall, Lick Observatory.

The distribution of neutral hydrogen gas in the galactic system, according to J. H. Oort, F. J. Kerr, and G. Westerhout, from the "Monthly Notices" of the Royal Astronomical Society. Compare this chart with Dr. Westerhout's drawing on page 367.

quite different from that for rigid-body rotation, with the greatest velocities at the least distances.

As illustrated on page 612 of last October's issue, radio observations of the hydrogen 21-cm. line give considerable information concerning the rotational velocities for regions of the galaxy nearer the center than the sun is. For parts farther from the center, we must depend on star distribution data, the velocities becoming very uncertain at more than 10,000 parsecs distance from the center. The results have been studied by M. Schmidt, of Leiden Observatory, who extended the curve plotted for distances from the center between 8,200 and about 12,000 parsecs. The dashed curve is drawn on the assumption that the innermost parts of the galaxy, from the center to about 1,500 parsecs, rotate nearly as a solid body.

Between 3,000 and 8,000 parsecs, the circular rotational velocity changes but little – it is neither pure solid-body nor pure Keplerian motion. Only at distances beyond the sun does the curve definitely decline, indicating motion more in accordance with Kepler's third law. Thus, we might visualize our galaxy as having a uniform distribution of stars in an inner nucleus and a scattering outside. The situation somewhat resembles the planet Saturn and its rings, the planet rotating mostly as a solid body and the particles of the rings obeying Kepler's laws.



The speed of rotation of our Milky Way at various distances from its center is shown by this chart after M. Schmidt.

Rotations of other spiral galaxies generally follow the same pattern. An example is M33, in Triangulum, for which N. U. Mayall has found solid-body rotation of the central parts and a falling off in velocities for the outer parts.

The large contour map represents the presently known spiral structure of the Milky Way as determined from the distribution of neutral hydrogen by means of radio telescopes in the Netherlands (see page 371) and at Sydney, Australia. This chart by J. H. Oort, F. J. Kerr, and G. Westerhout was discussed by them in the *Monthly Notices* of the Royal Astronomical Society, Vol. 118, No. 4, 1958. The sun's position is indicated by the

small circle in the upper part of the map, at an assumed distance of 8,200 parsecs from the galactic center, which is labeled with a *C*.

The left side of the drawing represents mostly observations made at Sydney. The right side, from about galactic longitude 200° clockwise to 340°, corresponding to the arc of the sky from Canis Major to Sagittarius, is based on Dutch results. Since the methods and equipment used by the two groups were not the same, structure indicated on the right is more detailed than that at the left. Nevertheless, in the region of overlap the Northern and Southern Hemisphere observations are in good agreement.

At first glance, the large number of roughly circular arms or branches in this picture seem to be more ragged and irregular than the corresponding features in nearby spirals like M33. However, Oort and his colleagues point out that several arms can be traced for considerable lengths.

The sun appears to be situated near the inner edge of an arm stretching out in the direction of Cygnus, toward longitude 50°, and this can be followed, with some breaks, clockwise to about longitude 340°, where the contour intensities are high. Though this arm is not shown in the direction of the anticenter, between longitudes 135° and 160°, due to limitations of present techniques, it may be supposed that the Cygnus arm extends toward Orion, longitude 160°, and includes the Orion association of hot young stars. The Dutch observers call this entire structure the Orion arm. As we proceed along it clockwise, in the direction of galactic rotation, the distance from the center becomes less, decreasing from 8,500 parsecs at longitude 130° to 7,000 parsecs at 340°.

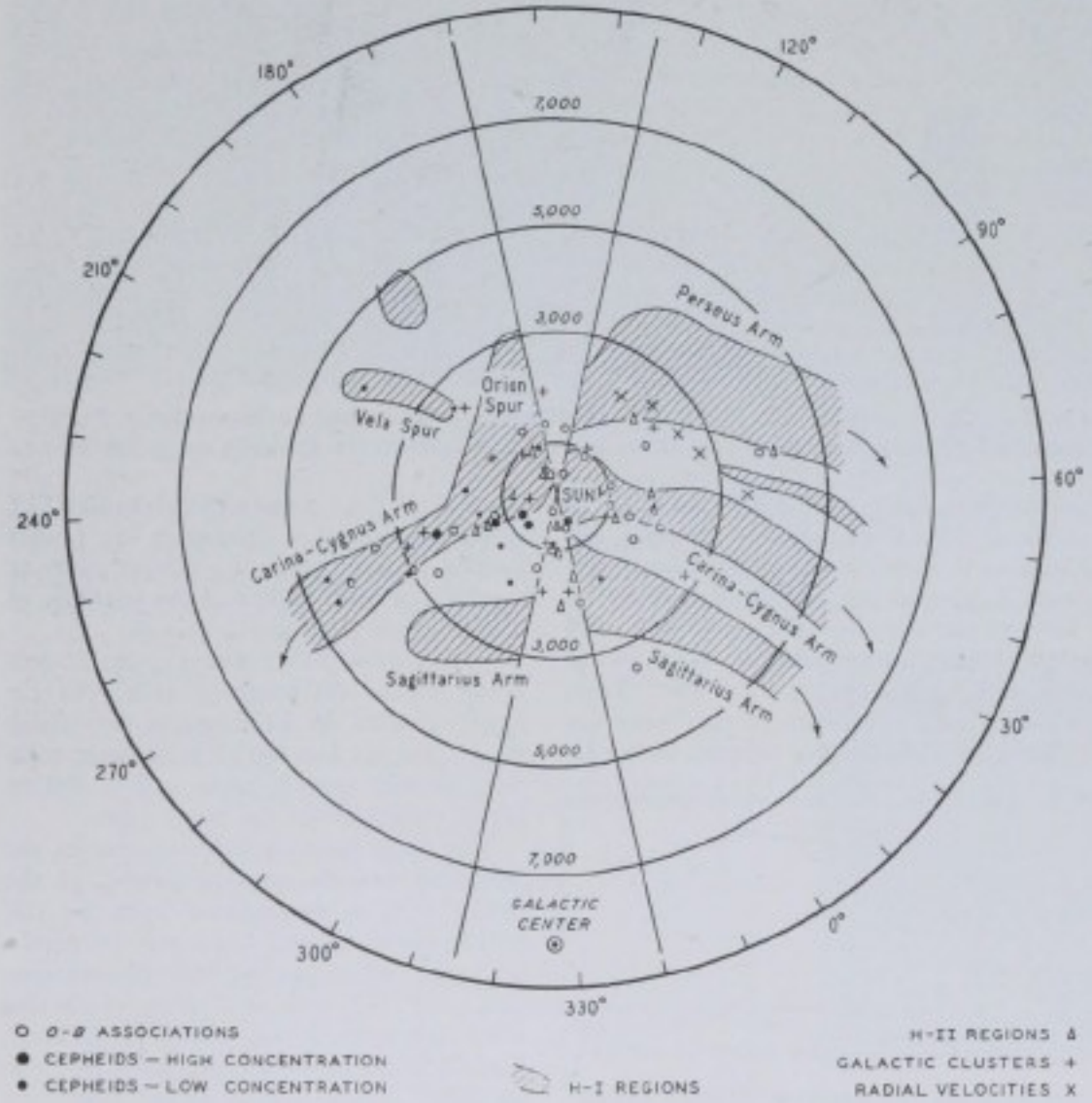
Well outside the sun is a conspicuous formation, the Perseus arm, extending from longitude 130° in Auriga to perhaps 30°. The almost circular shape of this arm is indicated by distances from the center of 10,500 and 10,000 parsecs in these directions, respectively.

Two spiral arms, at least, occur in the direction of the center. One, the Sagittarius arm, lies between 1,000 and 2,000 parsecs from the sun and appears to spiral in toward the center if followed in a clockwise direction. The other, an expanding arm indicated by the arrows, is about 3,000 parsecs from the center and is known to lie between longitudes 303° and 331°; it may extend all the way around the center (see SKY AND TELESCOPE, October, 1958, page 622). Oort and G. W. Rougoor interpreted radio observations of this arm as indicating a rotational velocity of 200 kilometers per second, while different parts of the arm move outward at between 30 and 200 kilometers per second.

The preceding picture of spiral structure is not adhered to by all astronomers. At Mount Stromlo Observatory, B. J. Bok is willing to accept the Perseus and expanding arms, but believes the Sagittarius and Orion arms, as described above, are not even tentatively established. He points out the important feature that extends from the sun toward the Carina region at longitude 255°, and ties this in with the Cygnus arm on the other side of the sky.

His diagram, sent recently to the British journal *Observatory*, shows his attempt to bring radio and optical data into better agreement. As he remarked 20 years ago, an observer in the tropics should not find it difficult to accept the view that our system has a distant center in Sagittarius and a spiral arm passing from Carina through the sun toward Cygnus. He believes that several short spurs extend outward from the main Carina-Cygnus arm, one toward Orion, one parallel to that spur, and one toward Vela traceable to a distance of some 1,500 parsecs.

On this basis the Carina-Cygnus arm is nearly circular, while Oort's Orion-Cygnus arm definitely is not. In other words, the latter seems to fit the idea of the arms spiraling outward from the center better than the former. Though the combined radio and optical evidence seems to favor the hypothesis of arms trailing behind as the galaxy spins, Bok points out that there are only slight deviations from circularity and that his model should not be ruled out on this ground.



B. J. Bok's concept of the spiral structure of the Milky Way system within about 5,000 parsecs of the sun. From a letter submitted to "Observatory."

We may infer from various observations the type of spiral represented by the Milky Way system. A schematic drawing has been made by Westerhout, the actual density contrasts being smaller than necessary for proper reproduction. The minima between the arms are very shallow in many cases. Dr. Westerhout writes, "We have attempted in this picture to display every detail concerning positions and interconnection of arms, rather than to give accurate densities."

Ours is a relatively large spiral, its ill-defined outer boundary about 15,000 parsecs from the center. From the number of continuous arms that would be cut by a radius drawn from the center, and from the spacings of these arms, Oort and others have inferred that our system resembles the Andromeda nebula or M81 in Ursa Major, being of Hubble's type Sb or perhaps slightly more open.

The Milky Way is certainly much more compact than the loosely wound spirals M101 in Ursa Major and M33, but it does not have such tight spiral arms as the early Sb galaxy NGC 4594. Moreover, the central bulge of our galaxy, though very pronounced, is not comparable to

The spiral structure of neutral hydrogen clouds in our Milky Way galaxy, as indicated by 21-cm. radio observations in Australia and the Netherlands, was drawn by G. Westerhout, Leiden Observatory. The galactic center is indicated with a cross, the sun with a circle and dot. The actual density contrasts are smaller than suggested by this picture, the minima between the arms being very shallow in many cases. But arm positions and interconnections are shown in detail.

that of NGC 4594, according to Oort, Kerr, and Westerhout.

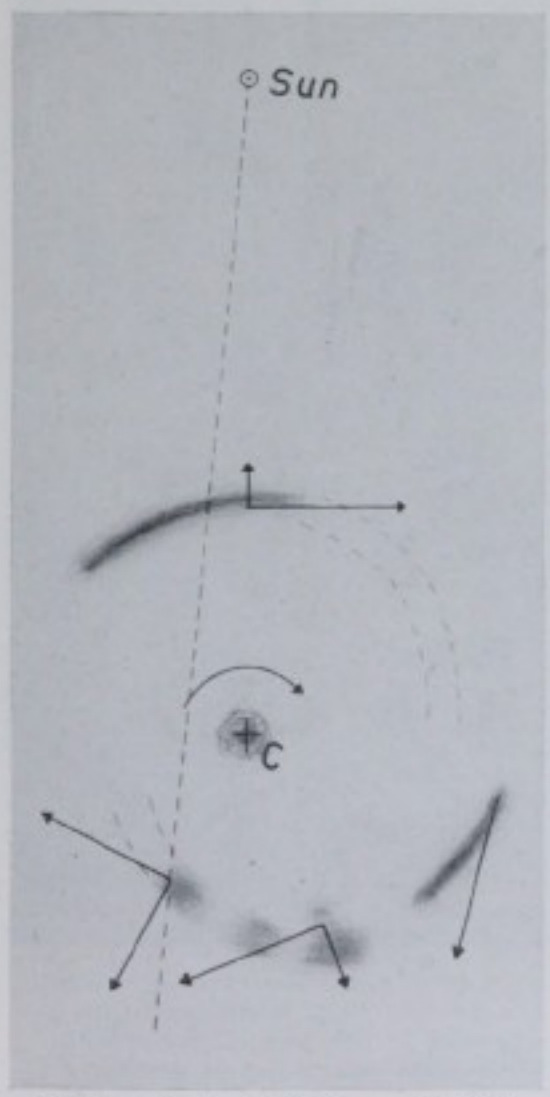
They add that another clue is furnished by the over-all fraction of mass in the form of interstellar gas. The percentage of interstellar hydrogen in the Milky Way galaxy increases as we go outward from the nucleus. Near the galactic center there is about 0.5 hydrogen atom per cubic centimeter — a figure that will need revision in view of the latest Dutch discovery (below) — while near the sun there are more than twice as many. Again, our system seems to be intermediate in type between the Andromeda nebula and M33, as two per cent of the mass of our system is interstellar gas, compared to 0.8 per cent and four per cent for the other two, respectively.

The most startling new information to be announced recently by the Dutch radio

astronomers pertains to the innermost sections of the galaxy. In a recent letter, Dr. Oort writes to me:

"We found pretty clear evidence of the existence of a small disk of neutral gas in the galactic nucleus. It has been roughly indicated on the enclosed sketch. It has a radius to half density of between 300 and 400 parsecs, a total thickness between half-density planes of 130 parsecs, and a mean density between one and two atoms per cubic centimeter. The remarkable feature of the disk is its extremely rapid rotation, which rises to about 200 kilometers per second at R about 100 parsecs, and then stays at this value up to the outer edge of the disk between 500 and 600 parsecs from the center.

"There is no reason to think that the gas in this disk would be expanding. On the contrary, it appears probable that it is a more or less stationary feature. These data permit an estimate of the lower limit of the stellar mass density. Within 150 parsecs from the center this should be between 500 and 1,000 times that in the neighborhood of the sun. This is a quite reasonable ratio, in view of the observed concentration of Population II objects toward the center."



This drawing by J. H. Oort and G. W. Rougoor shows the small patch at the galaxy's center discovered very recently by 21-cm. measurements. It is a disk of neutral hydrogen gas rotating with a high velocity. Concentric with it at a distance of about 3,000 parsecs are detached portions of an expanding spiral arm.

NEWS NOTES

NEW OBSERVATORY PLANNED FOR SOUTH AMERICA

A major new observatory is to be built in the Southern Hemisphere, in a project of the universities of Chile, Chicago, and Texas. The joint enterprise will be headed by Gerard P. Kuiper, director of Yerkes and McDonald Observatories, who recently examined three possible sites for a proposed 60-inch reflector in the vicinity of Santiago, Chile. Construction of the buildings by the University of Chile is to start within six months. The University of Chicago will provide the instrument, at a cost of about $160,000.

In a related development, the universities of Chicago and Texas are forming a joint astronomy department under Dr. Kuiper. This is an extension of cooperation begun in 1932. The University of Texas will expend $300,000 to improve the facilities at McDonald Observatory. A dormitory will be built for observers, an annex and visitors' gallery added to the 82-inch building, and auxiliary equipment provided for the 82-inch and 36-inch reflectors. In addition, funds are being sought for instruments for infrared and microwave observations.

AIRGLOW OF VENUS

Sporadic observations for more than three centuries indicate that the night-time side of the planet Venus sometimes shines with an ashen light (SKY AND TELESCOPE, January, 1958, page 123). And in 1954 the Soviet astronomer N. A. Kozyrev reported that in the spectrum of the dark side of Venus he had observed some 50 emission features, most of which he ascribed to molecular nitrogen. Verification of this finding and of the reality of the ashen light has long been needed.

Just as in the case of the earth's atmosphere, there should be airglow on Venus, and if the planet has a magnetic field auroral activity might be visible on its night side. To observe the spectrum of such radiation, Gordon Newkirk, Jr., has employed a fast, low-dispersion spectrograph in a coronagraph-type optical system at the High Altitude Observatory, Climax, Colorado.

On the basis of observations during five evenings in January, 1958, Dr. Newkirk has been able to confirm two of Kozyrev's emission features, at wave lengths of 4415 and 4435 angstroms. The identity of the molecules causing these is not known, nor whether the phenomenon is of auroral or airglow character. In addition, a previously unreported emission band may be present at 4505 angstroms.

From the intensity of the emission, and assuming it is uniformly distributed over the dark side of the planet, Dr. Newkirk concludes that the surface brightness of the Venus night sky is about 80 times more than the brightness of the terrestrial night sky in the light of oxygen at 5577 angstroms (a band that is absent in the spectrum of Venus). However, when Venus is viewed telescopically, the effect should be normally masked by scattered light of the earth's atmosphere. Dr. Newkirk suggests that an occasional brightening of the Venus emission could account for the ashen light reported by visual observers.

This investigation was described in the January, 1959, number of *Planetary and Space Science*, a new journal devoted to the borderland between geophysics and astronomy, with particular reference to rocket and artificial satellite results. The editor is Milton Greenberg, Geophysics Corp. of America, and it is published by Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.

NOVA CHAMAELEONTIS 1953

A nova that flashed up during the year 1953 in the southern circumpolar constellation Chamaeleon has been discovered by the German astronomer Cuno Hoffmeister, from photographs taken during an expedition he made to South-West Africa.

The star was brightest — magnitude 7.3 — on the first plate showing it, April 10-11, 1953, and declined to magnitude 11 by July 12th of that year. Dr. Hoffmeister, who is director of Sonneberg Observatory, could find no trace of the nova on photographs of earlier years, and concluded that it must have been fainter than 15th magnitude before the outburst. The 1900 co-ordinates of the nova are $13^h\ 16^m\ 26^s$, $-81°\ 49'$, according to *Circular* 1671 of the International Astronomical Union.

INTERNATIONAL MEETING OF PLANETARIUM EXECUTIVES

Representatives from major planetariums throughout the world will attend six days of conferences at New York, Philadelphia, and Boston, on May 11-16. The first three days will be spent at the American Museum-Hayden Planetarium in New York City, where three group discussions on planetarium operation will be held.

On Thursday, May 14th, the delegates will visit the Fels Planetarium in Philadelphia and tour the Flower and Cook Observatory of the University of Pennsylvania. The party will then go to Boston for an inspection of the Charles Hayden Planetarium and Harvard Observatory.

Besides 11 American planetariums, as many as eight foreign institutions may be represented: Planetarium Haagsche Courant, The Hague, Netherlands; London Planetarium, England; Sao Paulo Planetarium, Brazil; Montevideo Planetarium, Uruguay; Deutsches Museum, Munich, West Germany; Hamburg Planetarium, West Germany; Carl Zeiss Works, Oberkochen, West Germany; and Jena Planetarium, East Germany.

ROCKET OBSERVATIONS OF ULTRAVIOLET NEBULAE

A fairly detailed mapping of the sky in far-ultraviolet light of 1225 to 1350 angstroms wave length has been obtained by U. S. Naval Research Laboratory scientists, from the flight of an Aerobee-Hi rocket on the night of March 28, 1957, at White Sands Proving Ground. This ascent to 90 miles was a follow-up to the historic flight directed by the same group in November, 1955, when the first observations were made of far-ultraviolet radiation from celestial sources other than the sun. J. E. Kupperian, Jr., A. Boggess, III, and J. E. Milligan have reported the findings from the second ascent in the *Astrophysical Journal* (November, 1958).

The techniques of ultraviolet observations of the night sky were described by Otto Struve in this magazine last July (page 445). Four calcium-fluoride photon counters, in the side of the rocket, received sky radiation through bundles of tiny hollow nickel tubes. These limited the field of view of each counter to a circle three degrees in diameter. As the rocket rotated, the counters scanned strips of the sky, and since the orientation of the Aerobee was known for each moment, the scans could be pieced together to form a map of part of the sky.

Most of the ultraviolet radiation was found to come from extended nebulosities. In the 1955 flight, for which the counters' field of view was 20 degrees, several sources had been tentatively identified as the hot stars Regulus, Zeta Puppis, and Gamma Velorum. The improved resolving power of the 1957 experiment, however, shows that these sources are actually emission nebulae surrounding the stars, the latter being scarcely detectable.

Many of the conspicuous ultraviolet nebulae lie near the galactic plane, the brightest of them covering nearly the whole constellation of Orion. It may be a complex of very bright, individual nebulosities. There is an even larger ultraviolet area in Puppis and Vela, a neighborhood where many emission nebulae had previously been discovered photographically.

A second class of ultraviolet nebulae consists of isolated patches in high galactic latitudes. The most remarkable example is a roughly circular region about 22½ degrees in diameter, centered nearly one degree east of Spica, Virgo's brightest star. Fortunately, nine scans across this nebula were obtained during the 1957 rocket flight, so its structure could be well mapped. Approximately 60 per cent of the radiation came from a central core about 11 degrees across, but Spica itself did not register.

The existence of the Spica nebula was wholly unexpected, because there is no indication of it on photographs. If it is the same distance from us as the star, it would be 34 parsecs in diameter, and radiate 10^{31} ergs per second between the wave-length limits 1225 and 1350 angstroms. The origin of this surprisingly intense radiation poses a difficult problem. None of the possible mechanisms whereby Spica could cause the nebula to emit ultraviolet light seems adequate to account for more than a small fraction of the observed brightness.

VISITING PROFESSOR PROGRAM

Under a grant from the National Science Foundation, the American Astronomical Society will continue its program of visiting professors in astronomy for colleges and universities during the coming school year.

In the eastern states, address inquiries to Dr. Franklyn M. Branley, American Museum-Hayden Planetarium, New York 24, N. Y.; in the Middle West, Dr. Stanley P. Wyatt, University of Illinois Observatory, Urbana, Ill.; and in the West, Dr. Gibson Reaves, Department of Astronomy, University of Southern California, Los Angeles 7, Calif.

CINCINNATI ASTRONOMER DIES

Everett I. Yowell, who had been director of the University of Cincinnati Observatory from 1930 to 1940, passed away on March 12th at the age of 89. His main astronomical work was the cataloguing of stars with large proper motions.

AMERICAN ASTRONAUTICAL SOCIETY MEETING

The second annual meeting of the American Astronautical Society's western region will be held August 4-5 at the Ambassador Hotel, Los Angeles, California. Further information may be had from Alfred M. Mayo, Douglas Aircraft Co., Inc., El Segundo, Calif.

CORRECTION

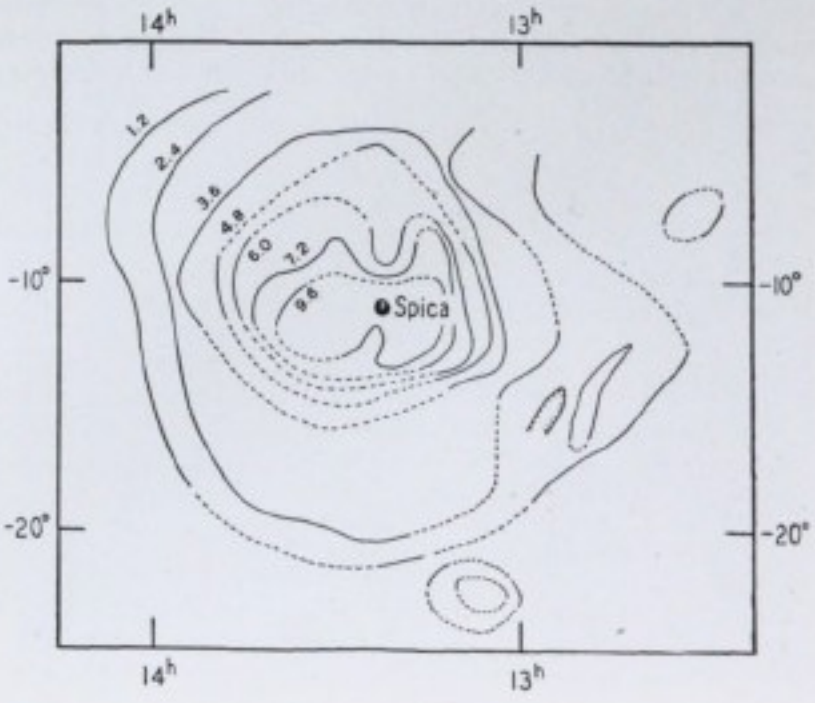
Several readers have pointed out an editorial error on page 252 of the March issue, where in a discussion of the evidence for vegetation on Mars it was said that lichens do not contain chlorophyll. Actually, all plants that carry on photosynthesis contain this substance.

IN THE CURRENT JOURNALS

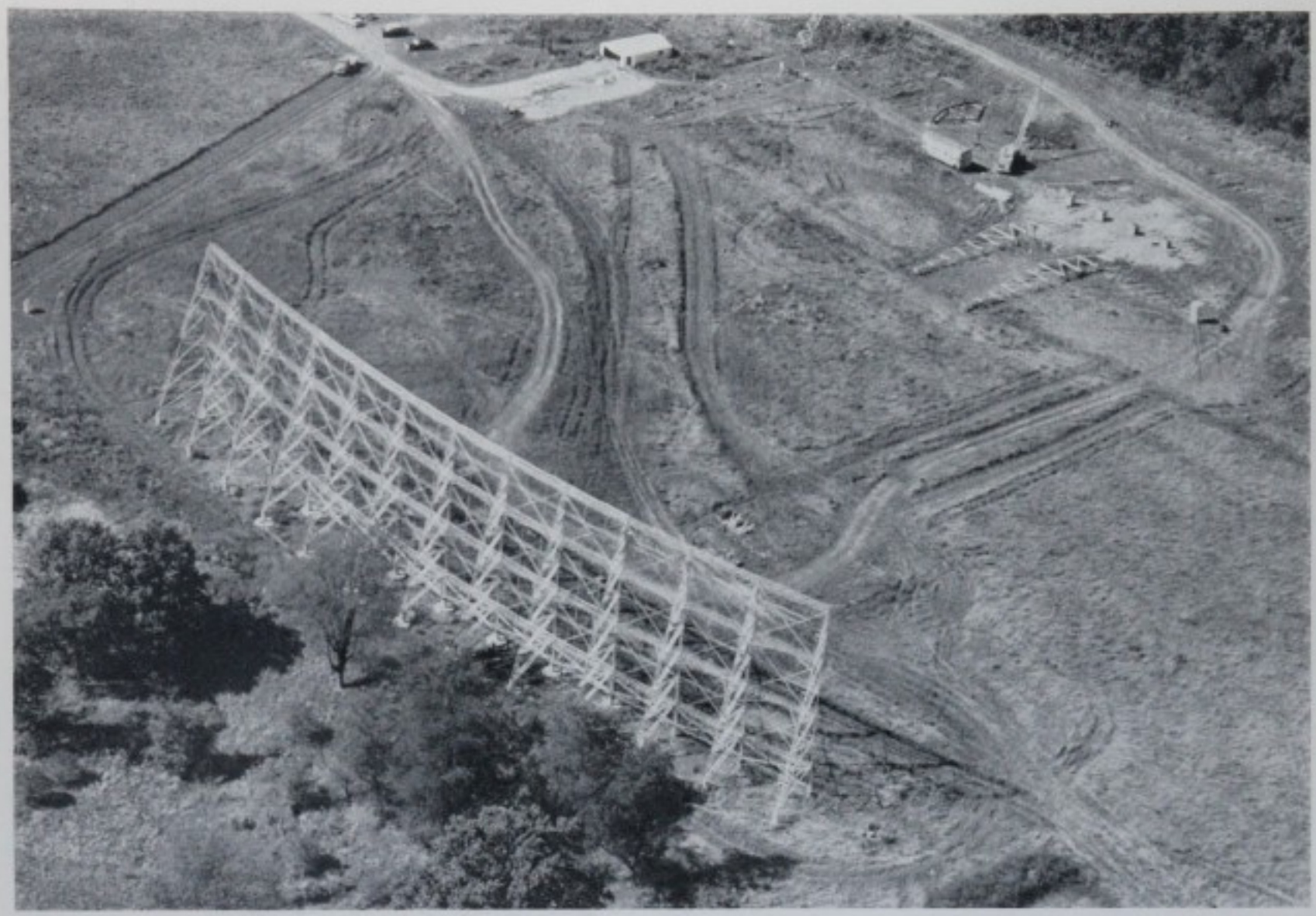
THE ROYAL GREENWICH OBSERVATORY AT HERSTMONCEUX, A. Hunter, *Journal* of the British Astronomical Association, January, 1959, page 4. "Nearly 400 acres of ground were acquired by the Admiralty with the castle, providing ample space for erecting telescopes as well as safeguarding the establishment to some extent against the encroachment of buildings. Today, twelve years after the purchase, the constructional work is complete and all the equipment has been installed."

RADIATION BELTS AROUND THE EARTH, by James A. Van Allen, *Scientific American*, March, 1959. "The inner belt reaches its peak at about 2,000 miles from the earth, the outer one at about 10,000 miles. Beyond 10,000 miles the radiation intensity diminishes steadily; it disappears almost completely beyond 40,000 miles. The maximum intensity of radiation in each belt is about 25,000 counts per second, equivalent to some 40,000 particles per square centimeter per second."

INTERFEROMETRICALLY CONTROLLED RULING OF TEN-INCH DIFFRACTION GRATINGS, by G. R. Harrison, N. Sturgis, S. P. Davis, and Y. Yamada, *Journal* of the Optical Society of America, March, 1959. "More than one-hundred test plane gratings have now been ruled on the large M.I.T. engine with interferometric control, as part of a program begun in 1948. Recently new levels of quality and size have been achieved. Seven gratings have been produced having ruled widths in excess of 10 in., and these show the weakest Rowland ghost and satellite intensities yet reported for ruled gratings. They give practically theoretical resolution even in the highest orders of the visible and near ultraviolet, equaling that produced by outstanding interferometers."



This chart of the ultraviolet nebula surrounding the star Spica was drawn from observed data obtained with a rocket that rose to 90 miles. The contours are labeled in intensity units of 10^{-4} erg per square centimeter per second. The nebula is considerably brighter toward its center. Naval Research Laboratory diagram.



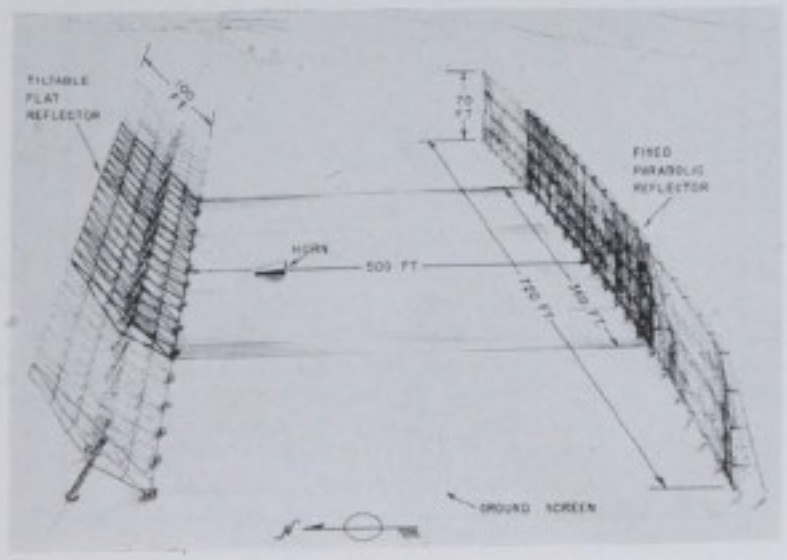
An aerial view from the southeast of Ohio State University's new radio telescope, showing its completed paraboloidal reflector component. The unit has a collecting area equal to that of a 170-foot-diameter dish antenna, at only 10 per cent of the construction cost. At the upper right are two sections of the 100-foot-high tiltable flat reflector now under construction. This flat will be set in declination, and the earth's rotation will provide scanning of the sky in right ascension. Tom Root photo.

SOME RADIO TELESCOPES—II

DELAWARE, OHIO

SITUATED on a 20-acre site about a third of a mile from Perkins Observatory is Ohio State University's unusual radio telescope, consisting of a large tiltable flat which reflects radio energy into a fixed paraboloidal reflector. The 360-foot-long, 70-foot-high paraboloid, shown in the aerial view, has been completed, and work has begun on the tiltable section. The telescope is expected to be finished next year.

The reflecting surface of the paraboloid consists of a curtain of over 3,000 vertical wires which all conform to within half an inch of its contour. The whole unit has 12 sections, each 30 feet wide.



The heavily drawn parts of this sketch show antenna sections now under construction. The lighter extensions are planned for the future. Ten Ohio State students, with three technical assistants, are building the instrument. The financial support comes from the National Science Foundation. This view is from the west.

The telescope will have an effective area of 25,000 square feet and is designed to operate at wave lengths of 15 centimeters to 15 meters. Observations will be made only along the meridian, like those with a transit instrument, at declinations between 35 degrees south and 60 degrees north.

Radio energy from celestial sources will be reflected by the paraboloid to its prime focus, where the power can be collected by a small horn antenna and conveyed to receiving equipment. Because of its wide frequency range, the telescope will be well suited for observing the spectra of localized radio sources and of the radio sky background. Extensive measurements at the 21-cm. hydrogen line are also planned.

The Ohio State installation was de-

signed by John D. Kraus, professor of electrical engineering, assisted by Robert T. Nash, graduate student and instructor in electrical engineering. Much of the construction is being done by university students, and the land site was provided by Ohio Wesleyan University. The project is financed by grants from the National Science Foundation, with supplemental aid by Ohio State University.

A radio telescope of similar design with a paraboloid about 1,000 feet long is being planned in Nancay, France.

DWINGELOO, NETHERLANDS

SINCE its dedication by Queen Juliana in 1956, the 82-foot radio telescope near Dwingeloo, Netherlands, has been used to investigate 21-centimeter radiation from the Milky Way and other galaxies, the cosmic continuum from 10 to 100 centimeters, the sun and solar flares. This instrument is part of the Observatory of the Netherlands Foundation for Radio Astronomy, set up by the Leiden, Utrecht, and Groningen observatories, with three other Dutch organizations.

The altazimuth-mounted paraboloid is located on a tower 49 feet high. The reflecting surface of 5,800 square feet is metal gauze with a 15-by-15-millimeter mesh. The telescope mechanism has an accuracy in both pointing and tracking of two minutes of arc.

While a telescope mounted in this fashion can be pointed anywhere in the heavens, it must also follow an object that the earth's rotation causes to move across the sky. To convert motion in equatorial coordinates to movement in altitude and azimuth, Dutch scientists designed a precision "pilot," pictured here. The pilot calculates the required motion for the dish and relays this information to the steering mechanism, allowing the telescope to track accurately the object under observation.

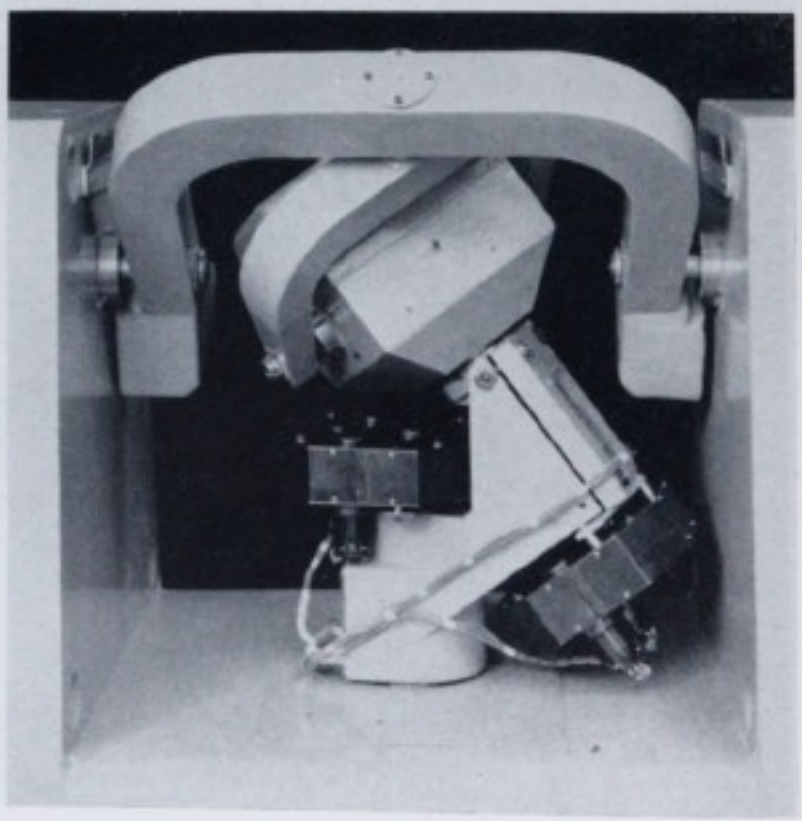
The Dwingeloo installation was begun in 1954. Funds for its construction were provided almost entirely by the Netherlands Organization for Pure Scientific Research.

ESCHWEILER, WEST GERMANY

THE first big radio telescope in West Germany was the 82-foot altazimuth paraboloid of Bonn Observatory, which was erected at Eschweiler in 1956. It is mounted on a tower some 53 feet in height, and the big dish itself weighs about 22½ tons. The total height of the installation, with the dish vertical, is 155 feet.

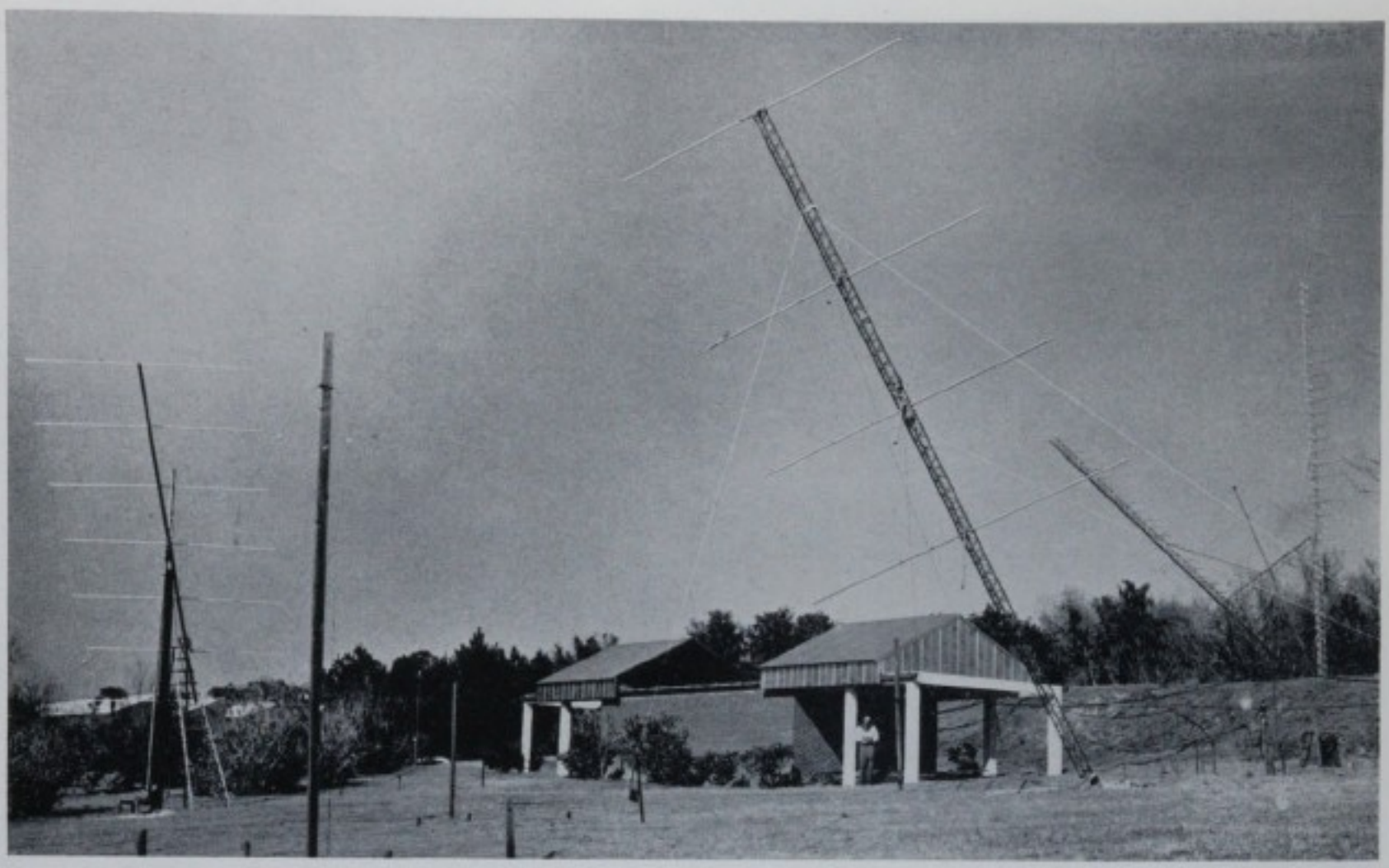
Made of light metal sheeting two millimeters thick, the dish is pierced with 10-mm. holes to reduce wind pressure. Its electrical properties at 21 centimeters, however, are practically identical with those of an unpierced surface.

This antenna can follow the stars automatically with the aid of an electrical



Above: The 82-foot radio telescope at Dwingeloo, Netherlands, is steerable in altitude and azimuth. The whole unit, including its concrete foundation, weighs about 400 tons. The steel frame, over which the mesh that forms the reflecting surface is stretched, consists of triangles one meter on each side.

Right: The pilot for the 82-foot Dwingeloo telescope mechanically converts motion in right ascension and declination to altitude and azimuth. Photographs on this page courtesy Leiden Observatory.



Three of the radio telescopes at the University of Florida are shown here, as well as a small optical observatory with a slide-off roof. At the left is a 27.6-megacycle Yagi array 36 feet long and mounted 20 feet above the ground. The 22.2-mc. polarimeter, right center, consists of two four-element Yagis set at right angles to each other on a common axis. The 22.2-mc. corner reflector is at the far right. University of Florida photograph.

drive. The ball-bearing assembly at the top of the tower has a rotational accuracy of 0.02 millimeter. The exterior diameter of the assembly is nine feet, while the individual ball bearings are five inches in diameter.

The receiver, constructed by the German firm Telefunken, permits the reception of signals 20 times weaker than the noise originating within the equipment. There are nine amplifying and three rectifying stages, with a total of about 200 vacuum tubes. The decimeter input section is built onto the dish and moves with it. Equipment for measurements and calibration is on the ground floor of the base structure.

GAINESVILLE, FLORIDA

RADIO NOISE coming from other planets is the chief interest of the radio astronomers at the University of Florida's Gainesville station. Their program began in 1956 and has steadily expanded. Extensive records have been obtained of radio noise from Jupiter (see page 380), and a watch has been kept for possible bursts of emission from Venus, Saturn, and Uranus. Of the three last, so far only Saturn has shown some uncertain indications of activity.

In 1956, planetary observations at 18.0 megacycles were begun with a broadside antenna array. Since any radiation originating from Saturn would probably be weak, a 22.2-mc. corner array was designed and set up for operation in 1957. Early the next year a 22.2-mc. polarimeter and Yagi arrays for 22.2 and 27.6 megacycles were put into use. Thenceforth five channels for recording noise were employed.

The 18-mc. broadside array consists of eight half-wave dipoles, arranged in two east-west lines 27 feet apart and 14 feet above a 133-by-82-foot reflecting screen. The latter is made up of 28 aluminum wires spaced a yard apart; as the wave length at which this radio telescope is used is 55 feet, the wires reflect almost as efficiently as a continuous metal sheet would. This array has a half-power beamwidth of 25 degrees east-west and 58 degrees north-south.

With this fixed array, a planet can be observed for only about three hours on any one night, around the time of meridian transit. To lengthen this interval, a steerable five-element Yagi array was

Bonn University's 82-foot radio telescope at Eschweiler, West Germany, is shown here as pictured on the October, 1956, front cover of the German radio magazine, "Funkschau." The dish is mounted on a 53-foot-high pedestal. It took only an hour to raise the antenna to the proper height and put it in its cradle. Picture courtesy Joseph Zelle, Cleveland, Ohio.

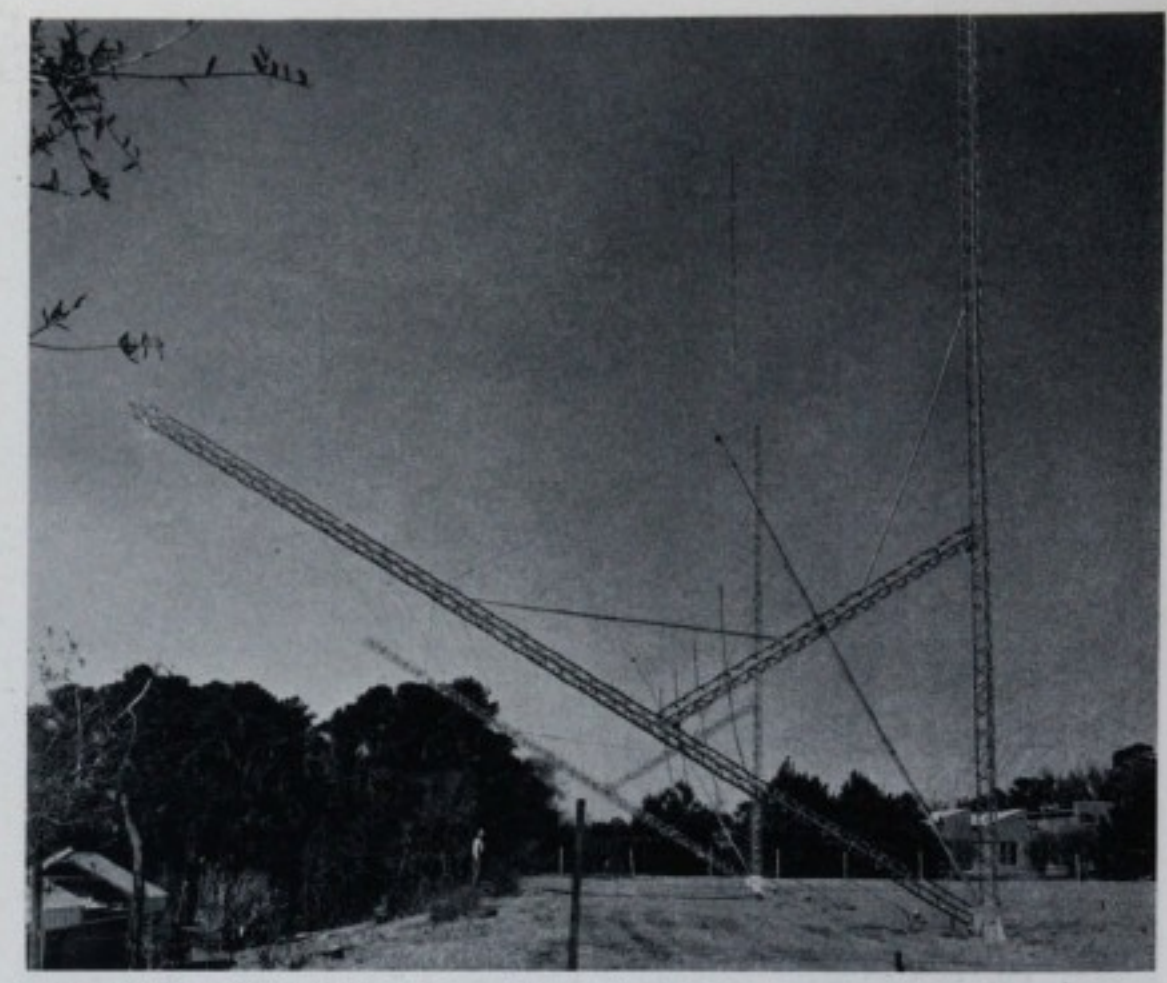
added. This 18-mc. unit is 36 feet long and is mounted 28 feet above the ground. A second steerable Yagi array, similar to the 18-mc. one, operates at 27.6 megacycles. Also 36 feet long, it is set 20 feet above the ground.

Another important Gainesville radio telescope is the 22.2-mc. corner array. It consists of four dipoles along an east-west line, suspended between two plane reflectors set at a 60-degree angle. The string of dipoles is parallel to the line of intersection of the mirrors, at a distance of about half a wave length. The entire assembly can be swung around this intersection line, from 30 degrees above the southern horizon to 30 degrees above the northern. The half-power beam-width is about 22 degrees east and west, and about 45 degrees north and south.

In order to investigate the polarization of radiation from Jupiter, a 22.2-mc. polarimeter was built. It contains a pair of identical four-element Yagi arrays, mounted along the same axis but with their polarization planes at right angles to one another. Both planes are inclined 45 degrees to the horizontal, and the common axis of the system can be steered along the celestial equator.

As the signals come in, they are received by each of the two arrays, actuating pen recorders. Analysis of the records shows the degree of polarization of the signal, and whether it is right- or left-handed. The observations made with this equipment have indicated that radio noise from Jupiter is polarized circularly or elliptically, and in the right-handed sense.

Further plans of the Florida radio astronomers include a station at Santiago, Chile, to be run in co-operation with the University of Chile. Since Jupiter and Saturn will remain in the southern sky for the next few years, this station would be much more advantageous for observations.

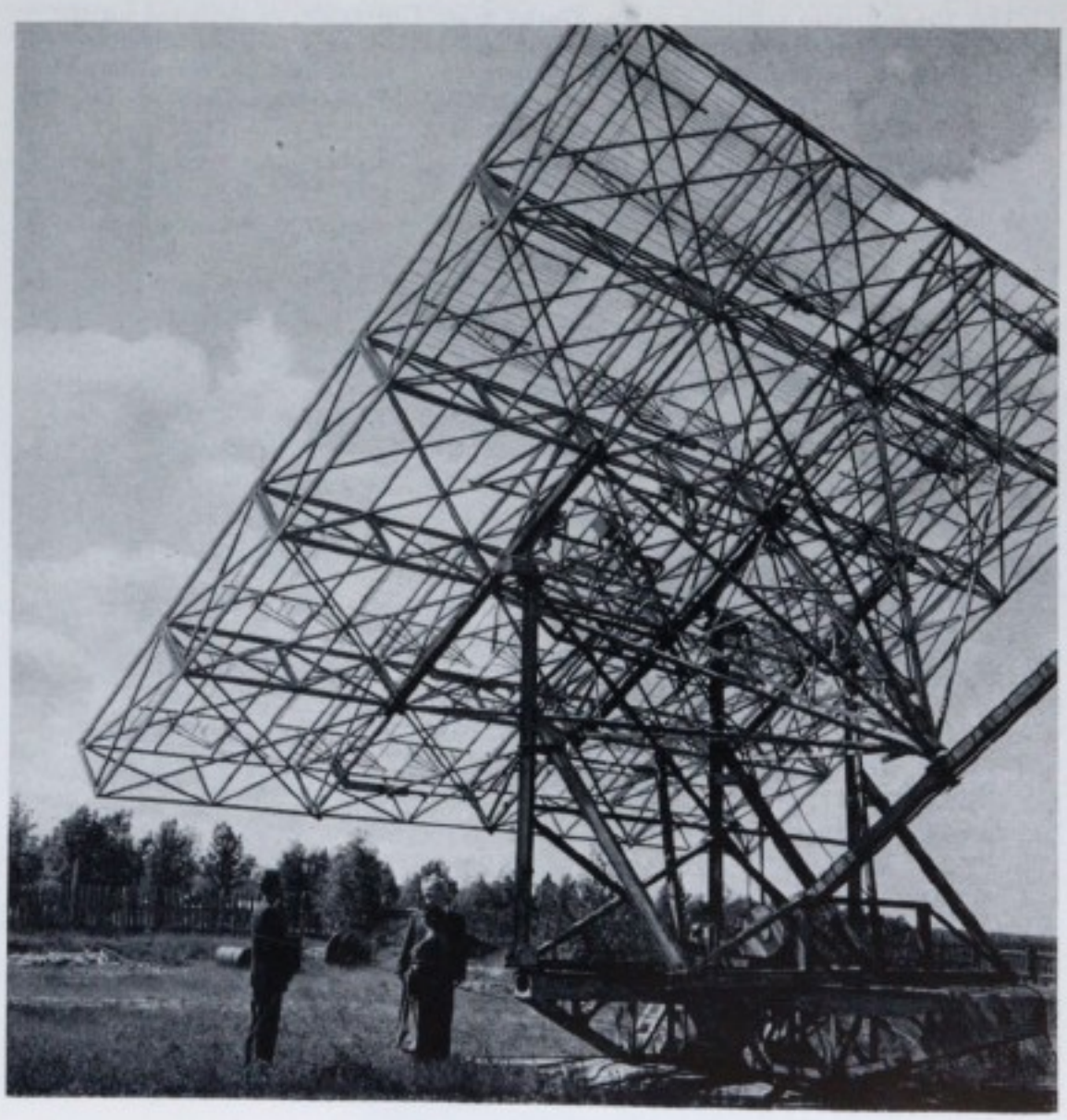


The "mirrors" of this 22.2-megacycle corner reflector consist of wires that are mostly invisible in the photograph. On the right, they extend from the vertical mast in the foreground to the one in the distance, on the other side from the oblique mast to the corresponding distant one. The masts may be swung north and south to change the pointing of the reflector in declination. The four dipoles that receive the radio energy are strung between the two shorter poles in the center of each V; the four leads from dipoles to the ground may be seen in the center. University of Florida photograph.

SOVIET UNION

SEVEN major radio observatories are presently in operation in the Union of Soviet Socialist Republics, according to the International Astronomical Union report by J. L. Pawsey (page 300, April issue). Equipment at these installations ranges from a 2-to-3-meter radio spectrograph for solar studies at the Crimean Astrophysical Observatory to the numerous instruments operated by the Crimean station of the Lebedev Physical Institute of Moscow, described last month. The latter organization also has a 66-foot reflector and a cross-type aerial, measuring 1,640 feet in each direction, near Serpukhov.

The largest radio telescope in the So-



Solar observations are made with this radio telescope at the Moscow station of the Research Institute of Earth Magnetism, Ionosphere, and Radio Propagation. Photograph by M. Redkin, courtesy U. S. S. R. Embassy in Washington, D. C.

The 20-foot radio telescope of the Gorky State University, as depicted on the front cover of the Russian magazine, "Radio," August, 1957 (supplied by Joseph Zelle, Cleveland, Ohio). The instrument is used for celestial observations at centimeter wave lengths. Photograph by E. Yasenov, TASS.

viet Union is used for observations of discrete sources. This gigantic array, which was pictured on the front cover of the January, 1959, issue of the Russian magazine *Radio*, is located on the grounds of the Burakan Astrophysical Observatory in Armenia.

Gorky is a major center of radio astronomy in Russia. V. S. Troitzky and G. G. Getmanzev, of the Research Institute of Radiophysics, have been using a 20-foot paraboloid, pictured here, for work at centimeter wave lengths. Several new instruments are proposed. These include a pair of 50-foot dishes, and a complex interferometer with lozenge-shaped antennas, the diagonal of each lozenge being 328 feet long. The former will be used for studies of radio emission at centimeter wave lengths, the latter for similar investigations at wave lengths greater than 10 meters.

One institution known to be active in research relating to the 21-cm. line of neutral hydrogen is the Poulkovo Observatory near Leningrad. The type of telescope available for this work is, however, unknown. A 400-by-10-foot reflecting array is available, but this is probably used for observations of the radio emission from the sun and moon, and "radio stars" or discrete sources.

One of the antennas situated near Moscow is that used by the Research Institute for Earth Magnetism, Ionosphere, and Radio Propagation, under the U. S. S. R. Ministry of Communications. It is pictured on the preceding page. Solar observations were made with this instrument at a variety of wave lengths as part of the program for the recent International Geophysical Year.

MITAKA, JAPAN

One of the five radio astronomy installations in Japan is operated at Mitaka by the Tokyo Astronomical Observatory. Shown here at the right is a 10-meter (33-foot) parabolic antenna, for observations at frequencies of 200 and 3,000 megacycles per second. At the left is one of two rhombic antennas which are connected for use as an interferometer and spectrometer. The Mitaka station is concerned mostly with investigations of the sun, as are the other Japanese radio observatories.

GETTING ACQUAINTED WITH ASTRONOMY

TIME AND THE SKY — IV

BRINGING a bright planet or star or a conspicuous star cluster into the field of your telescope is easy. Careful aiming of the instrument in the proper direction is enough to provide a magnificent view of Saturn's rings, Jupiter's moons, or the Pleiades.

Suppose, however, you wish to observe some object not visible to the naked eye. One way is to note its place on a star chart, and then slowly sweep over this part of the sky until the object is identified. This method can sometimes be rather laborious, but is the only way with hand-held instruments or a telescope on an altazimuth mounting.

There is a much more convenient procedure possible with equatorially mounted telescopes that are fitted with setting circles, as all professional instruments are and as all large amateur telescopes should be.

An equatorial mounting has two axes around which the telescope may rotate — the *polar axis*, parallel to the earth's axis of rotation, and the *declination axis*, perpendicular to it. Thus, turning the telescope around the polar axis moves it in right ascension only, and motion around the other axis is solely in declination.

Each of the axes carries a graduated circle. The one on the declination axis is marked in degrees, indicating 0° when the telescope is pointing toward the celestial equator and 90° toward the celestial pole. The circle on the polar axis is called the hour circle, and is marked in time units, its entire circumference amounting to 24 hours. When the circle reading is 0 hours, the telescope is pointing toward the observer's celestial meridian. Ordinarily the hour circle's divisions increase in both directions from this zero point up to 12 hours.

Using setting circles to point a telescope at a desired celestial object should be a fairly simple matter to anyone who has read the discussion of sidereal time on page 144 of the January issue, and of right ascension and declination on page 262 of March.

The main requirement is that the observer have some timekeeper showing local sidereal time. Professional observatories use a sidereal clock for this. The amateur, however, will find an ordinary watch adequate. Before starting an evening's observing, he should calculate the sidereal time corresponding to, say, 9:00 p.m. standard time, following the instructions given in the January issue. Suppose this turns out to be 12:36. Then if the observer sets his watch three hours and 36 minutes ahead, it will keep local sidereal time to within a minute or two during the whole night's observing.

Let us follow the observer outdoors to his telescope. The first sky object he selects for viewing is the fine globular cluster M3, in Canes Venatici. From an observing handbook, its 1950 co-ordinates are found to be right ascension $13^h\ 39^m.9$ and declination $+28°\ 38'$. (If great precision is desired, the position can be converted to that for 1959 by allowing for precession, as explained in the March article, giving $13^h\ 40^m.4$, $+28°\ 35'$. For amateur purposes, this step may generally be omitted.)

Large setting circles are features of the equatorial mounting of a 6-inch f/8 reflector made by Franklin Hosken, Calumet City, Illinois.

The telescope is now turned around the declination axis until the declination circle reads close to $+28°\ 38'$, and the declination clamp is tightened.

To make the setting in the other co-ordinate, a simple subtraction is first needed: *Hour angle equals sidereal time minus right ascension*. Thus, if the sidereal time is 13:00, the hour angle of M3 is 13:00 − 13:40 or −40 minutes, meaning that M3 is east of the meridian, and will not reach it for 40 minutes. (An hour angle of +3 hours would mean that the object had crossed the meridian that long ago.)

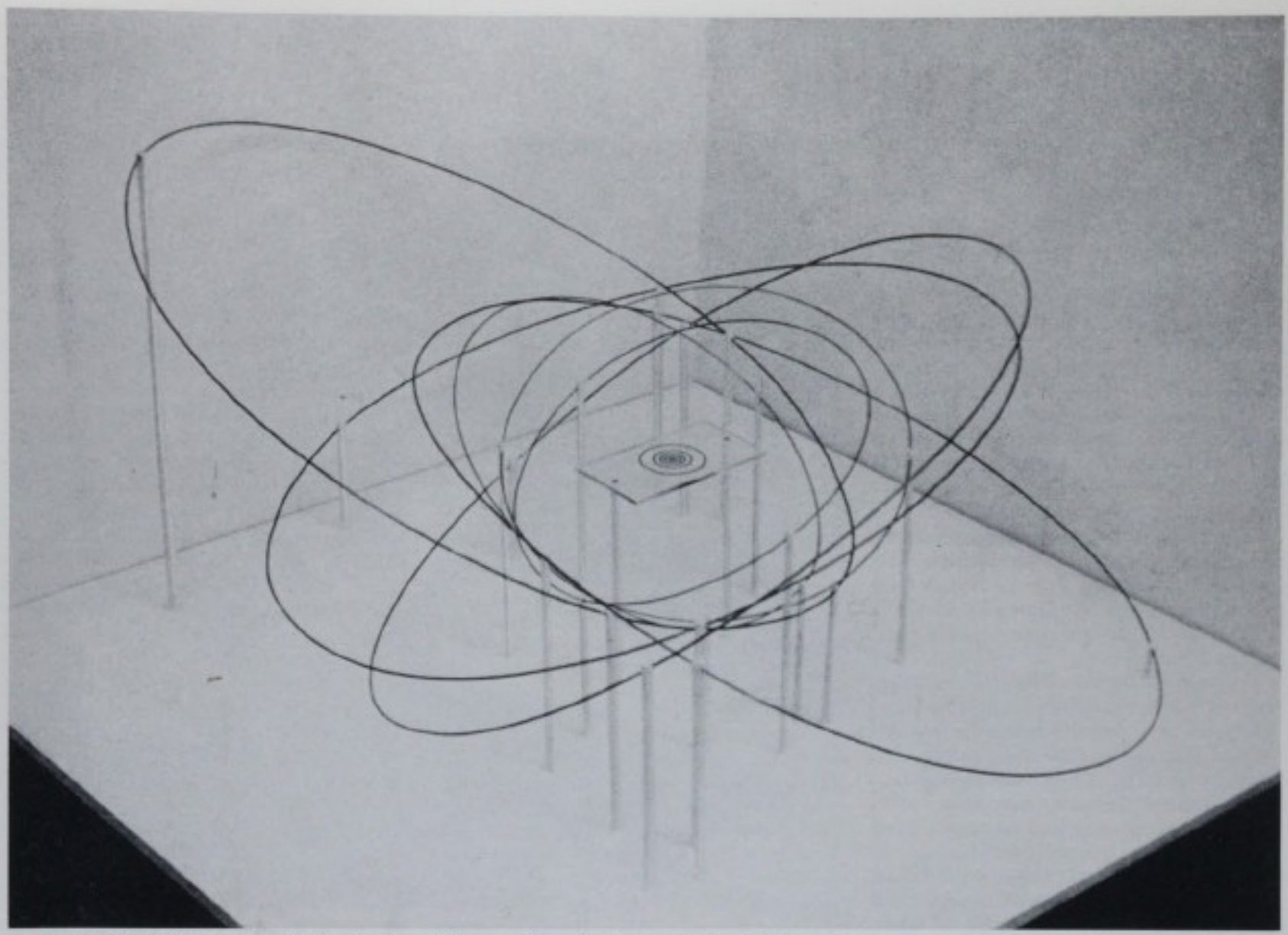
Therefore, the instrument is turned until the hour circle reads 40 minutes, with the telescope pointing east of the meridian. Looking in the finder, the observer should see M3 as a conspicuous soft glow. A slight shift of the telescope to bring the object into the center of the finder field should then place the cluster in the field of view of the main telescope.

This procedure of locating a sky object with setting circles becomes quite easy and rapid after a little practice. Try it first on a familiar bright star.

The process does require that the equatorial mounting be oriented fairly accurately. The polar axis should make an angle with the horizontal equal to the observer's latitude, and also be in a north-south vertical plane. Instructions for making these adjustments are given, for example, in chapter 12 of Allyn J. Thompson's book, *Making Your Own Telescope*.

Setting circles can also be used differentially for locating sky objects, a simple process that does not depend so critically upon the adjustments of the mounting. In addition, knowledge of the sidereal time is not needed. In this method, the telescope is first pointed at some conspicuous bright star in the same general sky area as the object sought. For instance, if we wish to observe M3, the star Arcturus is a convenient choice. This star's position is $14^h\ 13^m.4$, $+19°\ 26'$ (1950 co-ordinates), and so the cluster is 33 minutes of right ascension east of it, and nine degrees north. We point the telescope at Arcturus and read the circles. Shifting the instrument by the differences just given should bring M3 into view.

The globular cluster M3, photographed in red light. In small telescopes, the cluster stars blend together into a glow of light. Larger apertures, giving better resolving power and more light grasp, show the outer regions of such clusters resolved into closely packed faint stars. M3 is well situated for observation on May evenings.



A model of the system of Jupiter's satellites, made of wire and plastic by students at the American University, Beirut.

A Model of Jupiter's Satellite Orbits

OWEN GINGERICH, *American University Observatory, Beirut, Lebanon**

FREQUENTLY likened to a miniature solar system, Jupiter and its moons are one of the most remarkable sights in the sky. But the analogy is incorrect. While the five innermost satellites, including the four discovered by Galileo in 1610, form a compact group in the Jovian equatorial plane and are regularly spaced from the planet, with each successive period of revolution about double the one before, the seven outer moons present a scene of great complexity.

Not only are the orbits of the latter highly inclined and interspersed, but the four most distant move in a backward direction relative to the rest of Jupiter's system. Furthermore, there is no longer a steady progression in distance from the planet. Three are grouped at about seven million miles, and the average distance of the four retrograde satellites is 14 million miles. At these distances from Jupiter, the gravitational attraction of the sun plays a significant role, constantly changing the outer orbits.

The Galilean satellites are the largest and the brightest, being easily visible in a small telescope. Jupiter **V**, closest to the planet, and **VI** are both less than 100 miles in diameter and are visible only in large instruments. The remaining six, each less than 30 miles in diameter, are extremely faint, between 16th and 18th magnitude at mean opposition.

In this Lowell Observatory photograph, Jupiter's largest moon, Ganymede, is at the left, while its shadow (right) is starting across the planet.

According to Gerard Kuiper's protoplanet theory of the formation of the solar system, the seven outer satellites are objects that have been lost and recaptured by the planet. Proto-Jupiter, a large, massive object that grew from the surrounding solar nebula, must have had a retinue of protosatellites. As the sun condensed from the nucleus of the nebula and grew hotter, increased radiation pressure of sunlight forced gasses escaping from the protoplanets out of the solar system.

During this stage, the attraction of proto-Jupiter on the outer satellites became more and more tenuous due to its own loss of mass. Most of the satellites were eventually lost, according to Dr. Kuiper. Some probably became Trojan asteroids, trapped in Jupiter's orbit 60 degrees before or behind the planet, while others were recaptured, and could take random orbits, either direct or retrograde. The instability of the present orbits is such that the four outer satellites are still

*Now at Whitin Observatory, Wellesley College.

very loosely affiliated with Jupiter and could perhaps be lost again.

Many features of the motions of the Jovian satellites are easily visualized with the aid of a model of the orbits such as I built with the assistance of my students at the American University of Beirut. The first problem in this project was to choose a scale large enough to show the innermost orbit, yet small enough to keep the outermost within reasonable limits. The adopted scale of 1.5 centimeters for each 1,000,000 kilometers makes the largest orbit 71 centimeters in extent, and the smallest half a centimeter. In order to accommodate the eccentric orbits, the model was erected on a square base measuring 90 centimeters on each side, representing more than the distance between Mercury and the sun!

One phenomenon nearly prevents the construction of a meaningful model. The perturbations of the outer satellites are so great that the orbital elements change rapidly, and vary over a wide range. For example, **VIII** and **IX** never duplicate their paths on successive revolutions, and the elements given for **XI** and **XII** are only approximate. Thus for each satellite an *osculating* orbit was adopted, showing how the motion would have continued from a certain instant if there were no perturbations.

The data on which our model is based appear in the table, where the satellites are listed in the order of their distances from Jupiter. For the outer moons with rapidly changing elements, an attempt was made to select values for 1938, and these were further reduced to a uniform reference system.

The second column gives the mean distances from Jupiter, and the third, the periods of revolution in days. The fourth column indicates the shapes of the orbits, ranging from circular, eccentricity 0, to highly elongated, eccentricity 0.50. Each

ORBITAL ELEMENTS OF JUPITER'S SATELLITES

Name	*Semimajor Axis (kms.)*	*Period (days)*	*Eccentricity*	*Inclin. (degrees)*	*Ascend. Node*	*Perijove*	*Date of Elements*	*Reference*
V	181,000	0.5	0.003	0	—	—	—	1
I Io	422,000	1.8	0.000	0	—	—	—	2
II Europa	671,000	3.6	0.000	0	—	—	—	2
III Ganymede	1,071,000	7.2	0.002	0	—	—	—	2
IV Callisto	1,884,000	16.7	0.008	0	—	—	—	2
VI	11,500,000	252	0.158	31	140°	271°	1938	3
X	11,600,000	255	0.141	28	81°	254°	1938	5
VII	11,800,000	262	0.207	29	196°	331°	1938	4
XII	22,200,000	676	0.17	147	227°	314°	1952	9
XI	22,600,000	694	0.21	163	232°	128°	1938	8
VIII	23,600,000	741	0.50	153	33°	272°	1938	6
IX	23,800,000	750	0.28	157	47°	112°	1938	7

Reference: 1, van Woerkom, *Astr. Papers of the Amer. Eph., XIII*, 71, 1950. 2, Russell, Dugan, and Stewart, *Astronomy, I*, 1945. 3 and 4, Bobone, *Astronomische Nachrichten*, 262, 321 and 401, respectively, 1937. 5, Wilson, *Publications* of the Astr. Soc. of the Pacific, *51*, 241, 1939. 6, Grosch, *Astronomical Journal*, *53*, 180, 1947. 7, Nicholson, *Astrophysical Journal*, *100*, 62, 1944. 8, Herget, *P.A.S.P.*, *50*, 347, 1938. 9, Herrick, *P.A.S.P.*, *64*, 238, 1952.

orbit's inclination to Jupiter's equatorial plane is given in the fifth column. A value of more than 90 degrees means that the motion is retrograde (east to west).

The sixth column contains the direction of the line of nodes, measured in the planet's equatorial plane, from the projection of a line joining Jupiter's center and the vernal equinox. The line of nodes is the line of intersection between the satellite's orbit plane and the Jovian equatorial plane. The next column gives the perijove, the nearest point to the planet in each orbit; its direction is measured in the orbital plane from the ascending node.

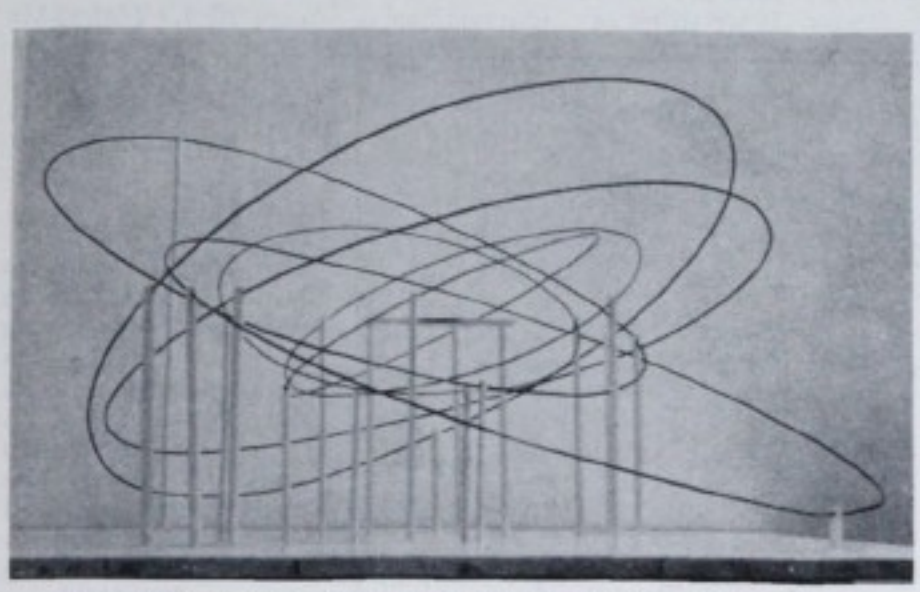
Notice that neither the ascending node nor the perijove is given for the five inner satellites, because their practically circular orbits lie almost exactly in Jupiter's equatorial plane.

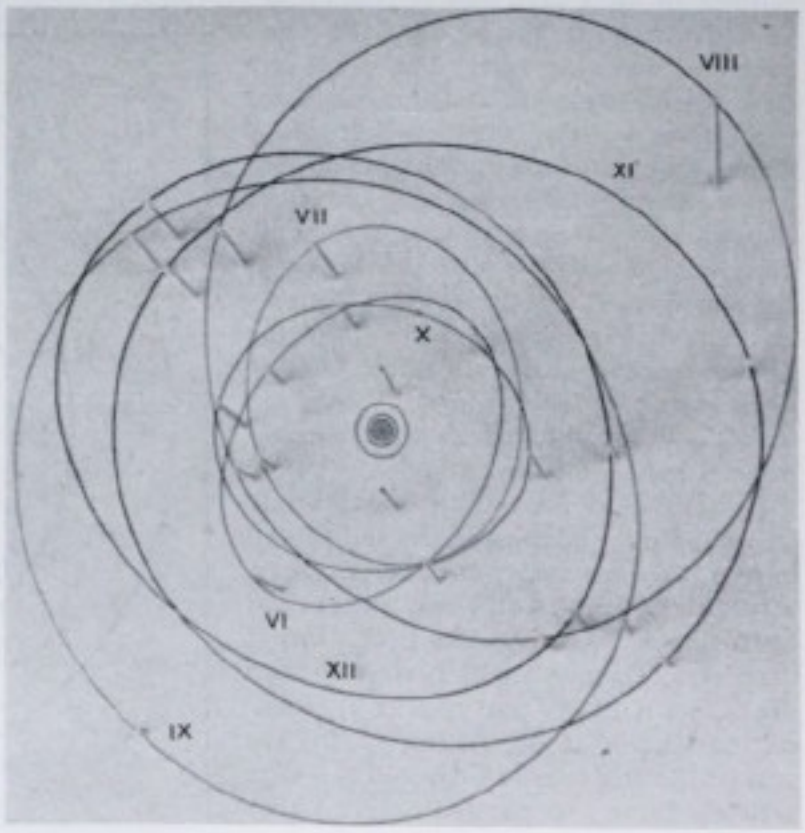
As a first step, ellipses were drawn to represent the orbit of each satellite. In our model, the small inner orbits are on a rectangle of transparent plastic, and the outer orbits were formed by bending tempered brass wire to shape against elliptical patterns. Next it was necessary to determine the orientations of the ellipses in space so as to ascertain the positions and heights of the supporting rods.

The sheet of plastic is held by two dowels 20 centimeters high. The outer orbits are supported at the nodes, at the same height, by dowels through which small holes were drilled in accordance with the angle of inclination. An additional support, which also holds the wire at the proper angle, was placed, when possible, at perijove or apojove. In the finished model, Jupiter **IX**'s orbit comes 18 centimeters below the plastic representing the equatorial plane, and **VIII**'s orbit comes 24 centimeters above.

The regularities in shape and orientation of the inner orbits are clearly illustrated in this model, as are the high eccentricities and inclinations of the outer. Moreover, the model shows that, in contrast to the great frequency with which Jupiter eclipses and occults the inner satellites, such phenomena for the outer ones are extremely rare.

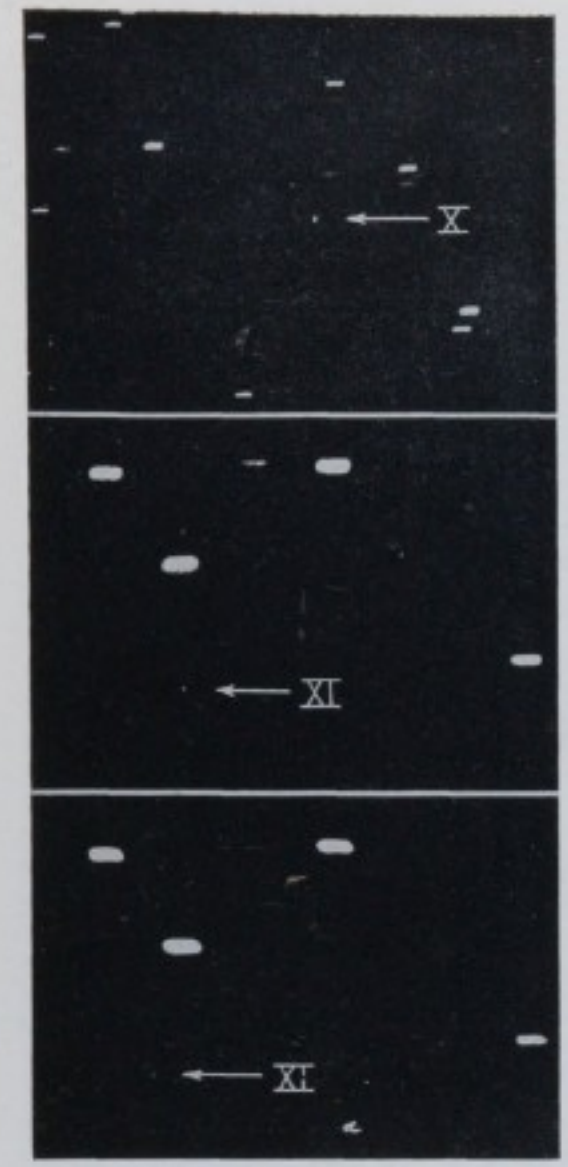
In addition, we see that solar eclipses on Jupiter are quite frequent. On each revolution Io, Europa, and Ganymede completely cover the sun for some part of the Jovian surface. As seen from the





Two further views of the model of the Jovian satellites illustrate some constructional details. Above, the model is viewed from a point in Jupiter's equatorial plane, so the plastic disk carrying the innermost orbits appears edge on. The other photograph of the model presents the system from a point above the pole of the planet, and the outer orbits are identified by the Roman numerals used to name the satellites.

OBSERVING THE SATELLITES



Two of Jupiter's outermost satellites, photographed with the 100-inch reflector by S. B. Nicholson in 1938. The lower pictures are one-hour discovery plates of XI, showing its motion relative to the background star trails. Mount Wilson Observatory photos.

planet, their respective sizes are five, 2½, and 2¼ times greater than the sun. The fourth Galilean satellite, Callisto, appears 1½ times larger than the sun, and causes eclipses on more than half its revolutions.

In contrast, transits by the outer satellites are extremely rare. The orbits are large, highly inclined, and the periods of revolution of the satellites are long. Hence, the outermost probably do not pass between Jupiter and the sun more than once in 200 or 300 years. In the middle group, moons **VI**, **VII**, and **X** transit the sun once in about 80 years, roughly as often as Venus does viewed from the earth. From Jupiter such outer satellite phenomena would normally require optical aid to be observed, as only **VI** could be seen with the naked eye.

Perhaps most interesting of all would be the annular eclipses of the sun caused by the tiny, innermost satellite, **V**. It revolves about Jupiter only two planet radii above the surface. So close is this object that its apparent diameter as seen from the planet is 40 per cent smaller at moonset than when at the zenith. Thus, the part of the sun's surface covered can vary between 20 and 60 per cent.

Venus Shots Planned for June

THE NEIGHBORHOOD of Venus is the announced goal of two interplanetary probes scheduled for launching June 3rd and 4th, under the auspices of the National Aeronautics and Space Administration.

Neither shot is expected to strike the planet itself. The first is intended to reach the vicinity of Venus about 150 days after launching and continue past it as an artificial planet revolving around the sun. The second probe, it is hoped, will be captured by Venus and become a satellite of it.

These ambitious ventures are far more difficult than launching an artificial earth satellite or a lunar probe. An interplanetary probe will require a higher velocity than yet achieved; unprecedented accuracy of trajectory will be needed to reach a small target area after some 240 million miles of travel.

For a flight to an inner planet such as Venus, the probe must be given an orbital velocity less than the earth's. To accomplish this, the launching has to be in a direction opposed to that of the earth's revolution, with a velocity more than escape velocity, but less than that of the earth in its orbit. As a result, the probe will be traveling in an elliptical path with the sun in one focus, the vehicle's motion being direct, not retrograde.

Maximum payload can be carried if this trajectory is exactly half an ellipse, whose aphelion is the earth's position at the beginning of the trip, and whose perihelion is Venus' position at arrival. Thus, as the diagram shows, the beginning and end points of the interplanetary voyage lie on opposite sides of the sun. This is an example of the class of trajectories proposed in 1925 by Walter Hohmann in Germany, which are often called *Hohmann ellipses*. If we think of the orbits of the earth and Venus as circles in the same plane, the Hohmann ellipse will be tangent to them.

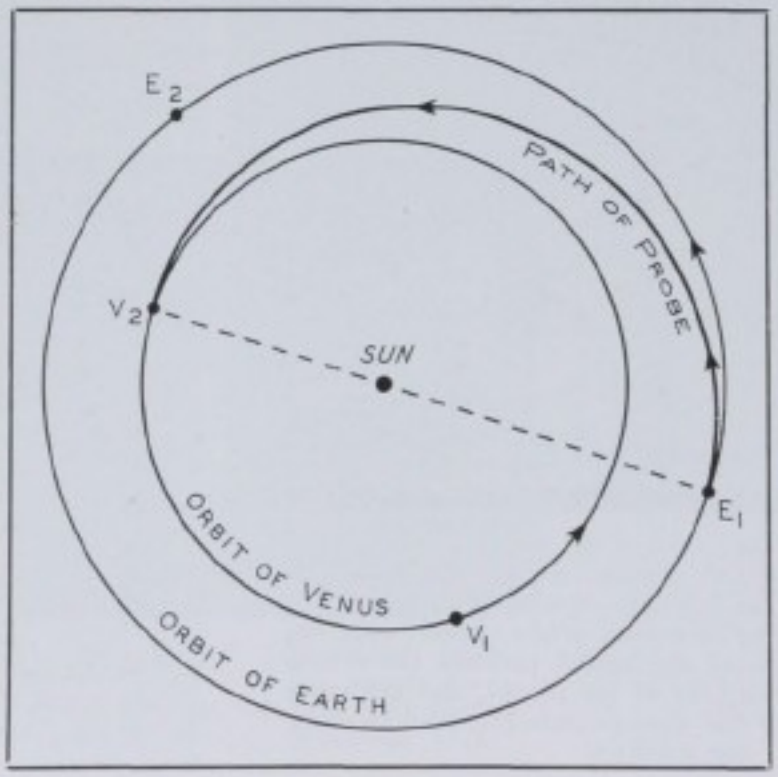
From Kepler's third law, the period of revolution of an object traveling in such an orbit is about 292 days, and the vicinity of the orbit of Venus will be reached in half of this, or about 146 days. Hence the launching date should be chosen so that 146 days later Venus will reach the point in its orbit lying directly opposite the earth's position at launching. Because the orbits of the two planets are slightly elliptical, the duration of the trip can differ by a little from this average value.

As quoted in the recent *Space Handbook* (see Sky and Telescope, March, page 259), the next favorable dates for beginning a flight from the earth to Venus are June 8, 1959; January 13, 1961; August 16, 1962; and March 28, 1964. For sending a probe to the vicinity of Mars, the corresponding times are October 1, 1960; November 16, 1962; and December 23, 1964. These dates recur at intervals approximately equal to the synodic period of the planet in question. In each case, a launching date several days earlier or later than listed here would give very nearly the same advantage.

While Hohmann ellipses offer maximum fuel economy in sending a vehicle to the neighborhood of Venus or Mars, the travel time — averaging 146 and 260 days, respectively — is not the shortest possible. Hence this kind of trajectory, while especially suited for instrument-carrying probes, may not necessarily be chosen for manned spaceflight.

Measurements of the Earth

THE geographical positions of several islands in the Pacific are being redetermined with great accuracy through observations of Vanguard I. The stable



This transfer orbit to Venus is a Hohmann ellipse drawn for a firing on June 4, 1959, when the earth will be at E_1 and the planet at V_1. A rocket launched then would follow the orbit to reach the vicinity of Venus at V_2 around the end of October, when the earth will have moved to E_2.

orbit of this long-lived satellite makes it very suitable as a reference mark. On the islands the U. S. Army Map Service uses Minitrack stations to track the satellite by means of the transmissions of its solar-powered radio (September, 1957, issue, page 530).

By comparing these measurements with others at Minitrack installations whose co-ordinates are precisely known, map errors of as much as a mile were found. Guam, Wake Island, Samoa, Ponape, Kwajalein, and Clark Field in the Philippines were the first sites selected for this study, which will be extended to a redetermination of intercontinental distances, presently uncertain by about 1,000 feet. The new technique should reduce the mapping error to about 240 feet.

Several of the Pacific islands already measured are bases for the radio navigation system known as Loran. Thus the accuracy of navigation in the central and western Pacific should be improved. The U. S. Navy has recently proposed a series of high satellites to serve in a new navigation system. Less expensive to maintain than Loran, these beacons would permit a ship to find its position in any weather, if ephemerides were published.

For over a decade, it has been realized that a flashing satellite would be very advantageous for geodetic work, as the flashes would allow simultaneous sightings from widely separated stations. The possibilities of this method have recently been analyzed at the Smithsonian Astrophysical Observatory by C. A. Whitney and G. Veis.

They propose a satellite moving in an orbit inclined 55 degrees to the earth's equator, and with a perigee height of 400 miles and apogee of 1,000. It would carry a xenon discharge tube, each flash lasting 0.01 second or less. At the observing sites, 10-inch f/7 telescopes would be used to photograph the flashes and the background star field. These techniques, the Smithsonian scientists believe, would suffice to give an absolute accuracy of about 100 feet to a world geodetic network.

Satellites Now in Orbit

ON APRIL 1st, seven artificial satellites were revolving around the earth, one of which, 1958β1, was lost. For the other six, current orbital data and further information are collected in the accompanying table. All of them are too faint for naked-eye observations.

The list does not include the Discoverer fired on February 28th. Roy Johnson, director of the Advanced Research Projects Agency, announced on March 17th that it is presumed no longer to be in orbit. Widespread doubts have been expressed that the sporadic radio signals attributed to this vehicle really proved it had gone into a satellite orbit.

An interesting problem was posed by the orbit of 1959α2, which is the rocket of the 21-inch weather sphere, Vanguard II. From early, inconsistent observations, it was at first thought that the rocket's period was 4.7 seconds shorter than the sphere's. After some days, the Smithsonian Astrophysical Observatory announced the period as about 130 minutes — a correction of four minutes!

One observer who realized that the first orbit of 1959α2 was seriously in error and corrected it himself was Arthur S. Leonard, leader of the Sacramento, California, Moonwatch team. His account is quoted here in part:

"Sacramento Moonwatch is not a conventional station. We have one 6-inch and two 4-inch refractors with overlapping fields, covering an arc of 2.9 degrees along the meridian. Our observational accuracy is a few hundredths of a degree and about 0.1 second in time. Since our 'fan' is very small, we have to make accurate predictions.

"After having observed 1959α1, we were among the teams requested, on February 24th, to locate α2. The next morning we observed both objects. . . . On succeeding mornings we regularly observed α1, but could not see α2. . . . By March 2nd, after five such failures, we decided to abandon the search on the predicted orbit and to make different hypotheses in order to recover it. . . .

"I made a careful analysis of all data on α2 which we had been able to obtain: a pair of observations from Walnut Creek, a meridian transit from China Lake, and one from our own station, all made . . . on the morning of February 25th, [and] a photograph made at Tokyo on March 2nd. [It was also known that α2] was at the same point as α1 at the instant of separation."

From these facts Mr. Leonard then proceeded on the assumption that the rocket had an orbital period considerably longer than the sphere's, and had been overtaken by it three times before the February 25th observations. "Three observers watched [for the predicted passage] on March 8th. The rocket passed well within the field of the middle telescope and crossed the meridian wire only 3.8 seconds later than the predicted time. . . . After that first morning it was not necessary to use more than one observer. I have subsequently observed it alone on 17 passes."

MARSHALL MELIN
Research Station for Satellite Observation
P. O. Box 4, Cambridge 38, Mass.

CHARACTERISTICS OF CURRENT SATELLITES*

SATELLITE	1958 α	1958 β2	1958 δ2	1958 ε	1959 α1	1959 α2
Name	Explorer I	Vanguard I	Sputnik III	Explorer IV	Vanguard II	(Rocket)
Launching date	February 1	March 17	May 15	July 26	February 17	February 17
Launching time (UT)	03:48	12:15:41	09:00?	14:59	15:55	15:55
DESCRIPTION						
Shape	Cylinder	Sphere	Cone	Cylinder	Sphere	Cylinder
Length (inches)	80	(6.4)	140	80	(21)	57
Diameter (inches)	6	6.4	68	6	21	18
Weight (pounds)	31	3.2	2925	37	23	51
Payload weight (pounds)	18	2.2	2135	18		None
INITIAL ORBIT						
Inclination (degrees)	33.22	34.26	65.1	50.33	32.86	32.88
Period (minutes) a = anomalistic, n = nodal	114.95a	134.29a	105.82n	110.3n	125.86	130.11
Perigee (miles above earth)	229	405	128	160	348	348
Apogee (miles above earth)	1578	2463	1160	1315	2064	2296
ORBIT SITUATION ON APRIL 1st, 0^h UT						
Longitude of ascending node (degrees west)	260	99	310	352	155	145
Nodal period (minutes)	111.15	133.98	100.20	101.81	125.68	129.95
Rate of change of period (minutes per day)	-0.008	-0.0008	-0.19	-0.046	-0.002	-0.002
Apogee (miles above earth)	1380	2454	840	901	2062	2294
Rate of change of apogee (miles per day)	-0.4	-0.04	-1.2	-2.7	-0.1	-0.1
Height over 30° north latitude (miles)						
South-to-north crossing	428	814	485	304	753	1021
North-to-south crossing	881	1746	778	250	1421	1821
Number of revolutions completed	5400	4073	4468	3342	485	468

*These data are from many sources, especially the Smithsonian Astrophysical Observatory and Space Track. Some listed values are estimated, and in a few cases the last two digits are uncertain. The lost satellite 1958β1 has been omitted.

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 101st meeting of the American Astronomical Society at Gainesville, Florida, in December, 1958. Complete abstracts will appear in the Astronomical Journal.

The Alpha Centauri System

About 4¼ light-years from the sun lies the visual binary Alpha Centauri. Composed of two stars of magnitudes 0.3 and 1.7, this is not only the nearest but one of the first discovered of all double stars. Some two degrees on the sky from this pair is found the 11th-magnitude red dwarf Proxima Centauri. As its name indicates, it appears to be closer to us than either of the brighter stars, and hence the nearest star to the sun.

Is Proxima an actual member of the Alpha Centauri system, or are we witnessing a chance encounter? The answer to this question depends on whether the motion of Proxima relative to the brighter stars takes place in a closed orbit (circle or ellipse) or in an open one (parabola or hyperbola).

Charles Gasteyer, of Van Vleck Observatory, Wesleyan University, has calculated on the basis of the masses, positions on the sky, and proper motions of the stars concerned, that the relative orbit will be elliptical if the parallaxes of Proxima and Alpha differ by not more than 0.032 second of arc with Proxima the nearer. The orbit may be a closed one if Proxima is within 0.18 light-year of Alpha's distance from us. Measures of the parallaxes of these stars from about 114 plates taken at Yale Observatory's station in the Southern Hemisphere give an absolute parallax difference (Proxima minus Alpha) of $+0.015 \pm 0.010$ second, within the limit above.

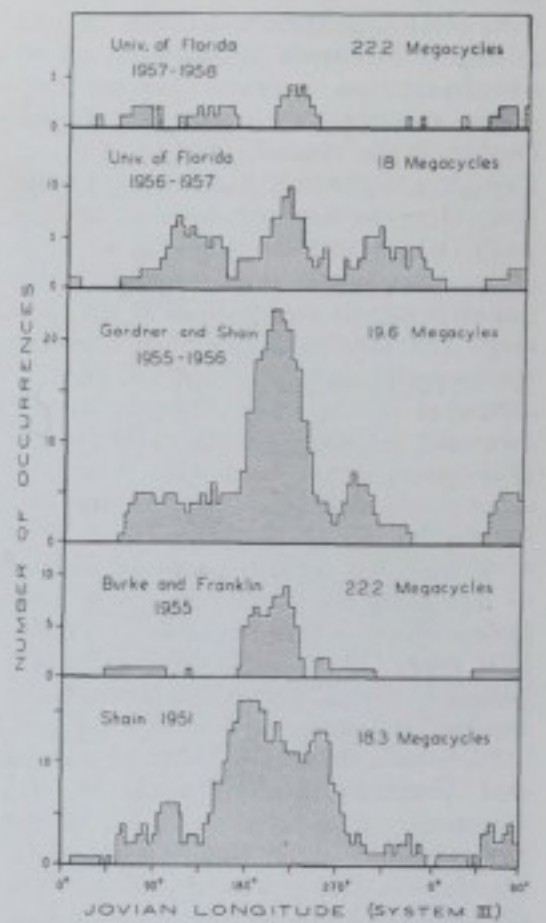
If the orbit is elliptical, the semimajor axis must be greater than 7,000 astronomical units (some 650 billion miles), and Proxima's period of revolution around the primary pair is more than 300,000 years. However, the eccentricity or shape of the orbit cannot be found unless we know the motions of the stars in our line of sight. This measurement depends on the Doppler shifts of the star's spectral lines, and Dr. Gasteyer feels that Proxima is too faint for a sufficiently accurate determination of its radial velocity. An uncertainty of only 0.2 kilometer per second could change the orbit from circular to parabolic – from an eccentricity of zero to an eccentricity of one.

In view of the other evidence, however, it seems likely that Alpha and Proxima Centauri form the nearest true triple star system.

Radio Studies of Jupiter

Recent results from observations of Jupiter's sporadic radio emission were reported by Thomas D. Carr, University of Florida, at the symposium on planetary radio astronomy. He described some of the equipment of the university's radio observatory shown on pages 372 and 373.

Listening to the "noise" of a Jupiter radio disturbance is an important part of identifying the planet's outbursts among static and other sources of radio energy that clutter up the receiver records. Over the loudspeaker of a short-wave receiver, the Jovian emission sounds like breakers rolling up on a beach – an irregular sequence of rising and falling hissing noises.

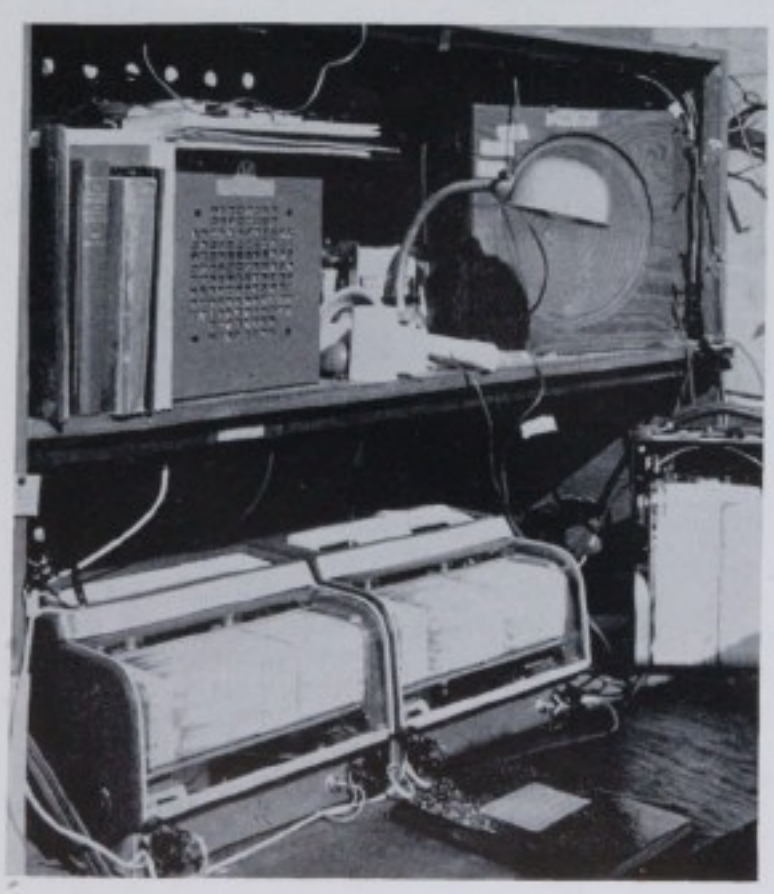


From five series of radio observations of Jupiter, T. D. Carr prepared this diagram to show that noise bursts came most often when the central longitude of the planet's disk was about 210°, in a co-ordinate system described in the text.

Each burst lasts from one to five seconds, some of them equaling a small solar radio outburst in intensity. Unsuccessful attempts have been made to correlate Jovian radio noise with individual markings on the planet visible through a telescope. However, data recorded over several months or more indicate an unmistakable variation of radio emission in synchronism with the rotation of the planet.

Since the solid surface of Jupiter is invisible beneath a thick cloud layer, optical astronomers can measure only the rotation of cloud features, and these have different periods. When the longitude of a visible marking is specified, one of two co-ordinate systems is used. Features in System I rotate at the rate of 360 degrees in nine hours, 50 minutes, 30 seconds, while System II has a period that is five minutes and 10.6 seconds longer. But none of the spots remains at a fixed longitude in either of these systems for any appreciable length of time.

Conditions in the earth's ionosphere affect the reception of Jupiter's radio energy in the frequencies where most of it has been observed – from 14 to about



At the University of Florida's radio observatory in Gainesville, three pen recorders indicate radio noise. The two recorders in the foreground are dual channel ones, giving a total of five channels. Two loudspeakers are used to monitor the output, and can be switched from one channel to another, two being monitored at the same time. They aid in distinguishing between the characteristic wavering hiss of planetary noise and terrestrial interference. Illustrations on this page courtesy of the University of Florida.

30 megacycles. Thus, reliable radio observations of the planet can be made only during the two or three months of the year when meridian transits occur between about 2 a.m. (local time) and sunrise. For this reason, the period of rotation established from radio data obtained during a single apparition of the planet is usually relatively inaccurate.

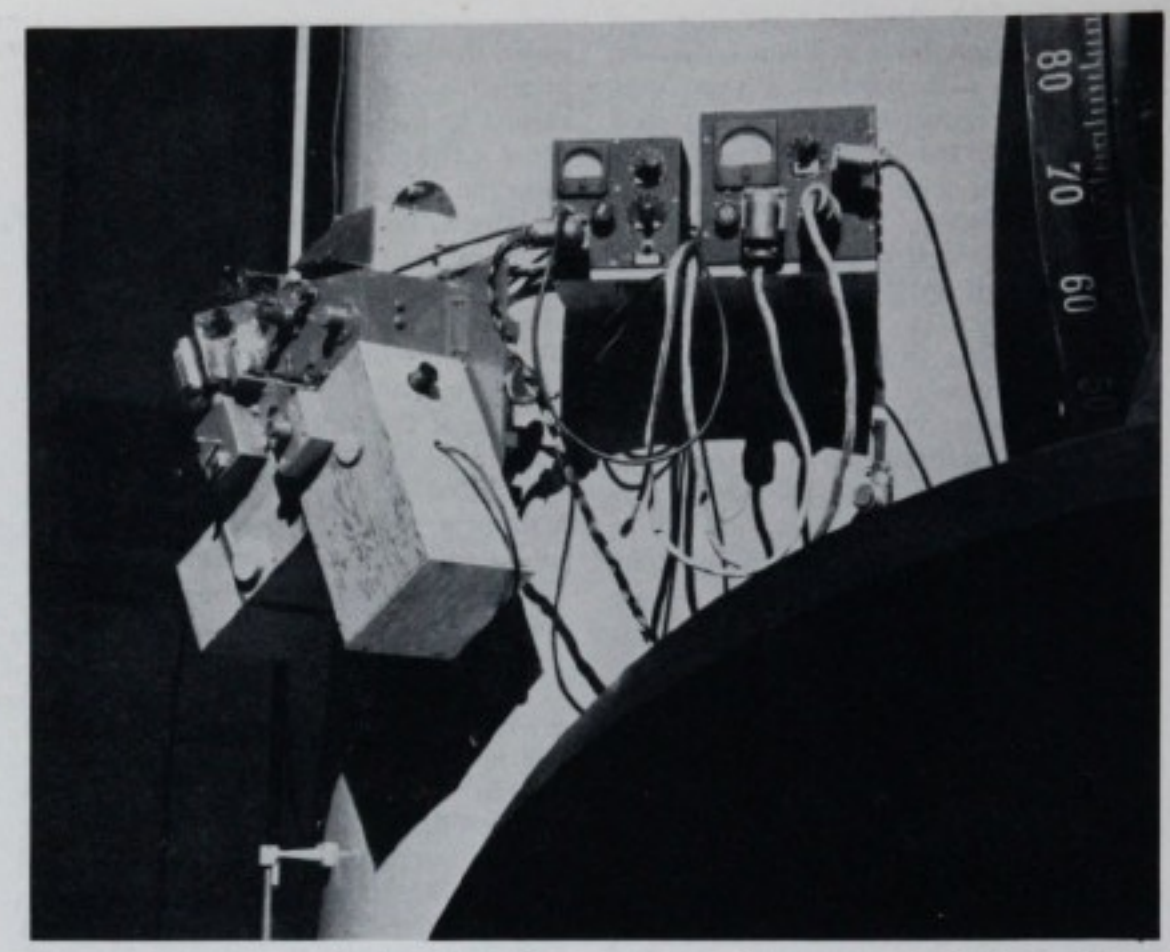
Considerably more accuracy has been obtained by Dr. Carr and his associate, A. G. Smith, by analyzing data from several apparitions obtained at Florida and elsewhere, as shown in the graph. They find that the regions of maximum and minimum activity appear to rotate with a constant period of nine hours, 55 minutes, 28.8 seconds. Therefore, they propose System III, another set of longitude coordinates rotating in 11.8 seconds less than System II, and coinciding with the latter on January 1, 1957.

As the chart shows, a main peak of Jupiter's radio emission occurs whenever the central meridian longitude is 210 degrees in System III. A period only one second longer or shorter would have changed the apparent peak longitude by 50 degrees in the course of five years. The apparent constancy of period from 1951 to 1958 seems to indicate that the radio source is anchored to the surface of Jupiter — as was first suggested by R. M. Gallet of the National Bureau of Standards — and does not drift about in its atmosphere. If this finding is definitely established, further radio records may give a very precise determination of the true rotation period of the planet's solid surface.

The discovery of Jupiter's sporadic radio emission was made in 1955 by B. F. Burke and K. L. Franklin, at the Carnegie Institution of Washington. They also found the emission to be elliptically polarized, indicating that the planet has both an ionosphere and a magnetic field. To study this effect, the Florida radio astronomers have set up a polarimeter to determine the ratio of the major and minor axes of the polarization ellipse for each burst of energy from Jupiter.

The polarization equipment was used on six nights in the spring of 1958, and many bursts were observed. In every case the radiation was right-hand elliptically polarized, though the ratio of the axes varied in apparently random fashion. From these results, the intensity of the magnetic field in Jupiter's ionosphere is tentatively estimated to be about seven gauss.

In coming years, the planet Jupiter is going to be located in the southern part of the ecliptic, rather far south for favorable observation from mid-northern latitudes. Therefore, Dr. Carr has proposed that the University of Florida establish an auxiliary planetary radio observatory in the Southern Hemisphere, in co-operation with the observatory of the University of Chile near Santiago. Both Jupiter and Saturn would be intensively observed from such a station, and correlation with simultaneous radio observations in Florida would provide means to evaluate the effects of the terrestrial ionosphere on the reception of planetary bursts.



William Liller used this photoelectric spectrophotometer, attached to the Curtis Schmidt telescope, for his observations of the Orion nebula. Optical parts are at the left, while the plywood boxes contain red- and blue-sensitive photomultiplier tubes, chilled with dry ice. To the right of these are the amplifier and power supply. University of Michigan Observatory photograph.

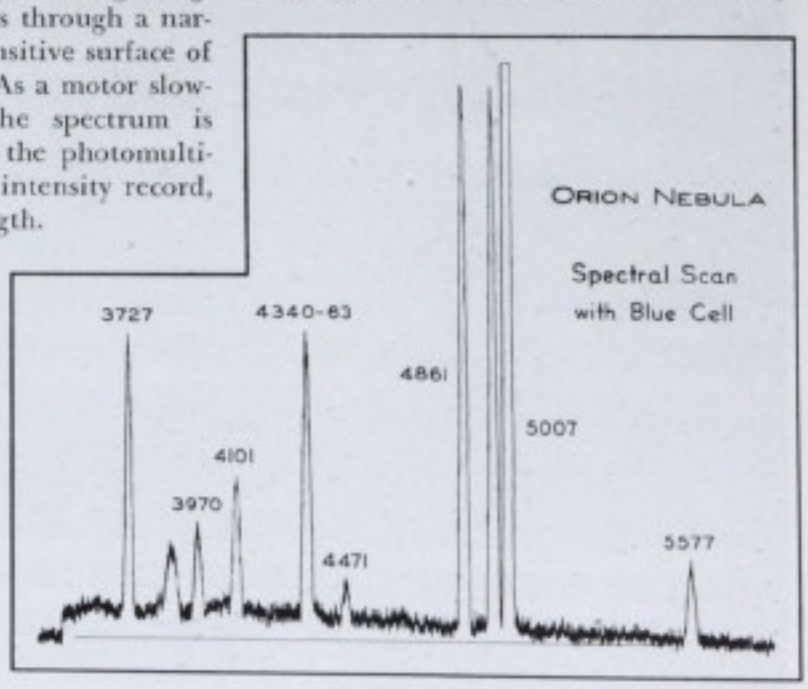
Orion Nebula's Composition

One of the most important problems in astrophysics is to determine the abundances of the chemical elements in nebulae and stars. For work on gaseous nebulae at the University of Michigan Observatory, a photoelectric spectrophotometer has been in use since December, 1955, attached to the 24-inch Schmidt telescope at the Portage Lake observing station.

This device is a grating spectrograph, employing a 15,000-line-per-inch grating. The diffracted light passes through a narrow slot onto the light-sensitive surface of a photomultiplier tube. As a motor slowly turns the grating, the spectrum is scanned by the slot, and the photomultiplier output provides an intensity record, wave length by wave length.

The spectrophotometer is shown above, mounted outside the tube of the telescope, at what is equivalent to its Newtonian focus. Light from the telescope enters the photometer from the top in this arrangement, through ultraviolet-transmitting optics. On the extreme left of the photometer is a counter that indicates the wave length being scanned, within two or three angstroms. The system provides for scanning the spectrum at rates of 30, 90, and 270 angstroms per minute.

Reproduced here is a typical record obtained with this equipment, of a portion of the spectrum of the Orion nebula. Most of the lines are due to nebular oxygen, hydrogen, and helium, but the one at 5577 angstroms originates in the earth's atmosphere. From nine similar tracings,



Part of the Orion nebula's spectrum, the peak heights indicating emission-line intensities. The strongest line, at 5007 angstroms, is of doubly ionized oxygen; 4861 is due to hydrogen, and 4471 to helium. The oxygen line at 5577 is of terrestrial origin.

Michigan astronomers William Liller and Lawrence H. Aller have made a quantitative chemical analysis. They also used photographic spectrum measurements made many years ago by A. B. Wyse at Lick Observatory.

As a preliminary step, they deduced that there are on the average 4,000 free electrons per cubic centimeter in the central part of the Orion nebula, and that the temperature of this electron gas is 9,000° absolute. Then they converted the measured line intensities into the abundances of the elements. The most uncertain step in their calculations was in allowing for the distribution of the atoms of a particular element among its different stages of ionization.

Hydrogen is by far the commonest element in the Orion nebula. Also, for every 1,000 atoms of oxygen, there turn out to be about 1,600 of neon, 130 of nitrogen and sulfur, 40 of argon, and two of chlorine.

These relative abundances for the most part closely parallel those in early-type stars (like Algenib) studied in this way by the Michigan astronomers. Chlorine, however, seems more abundant in the stars by a factor of 20 or 30. Earlier findings that the Orion nebula was abnormally rich in sulfur (Sky and Telescope, May, 1956, page 310) are not confirmed. However, even the new values for sulfur, chlorine, and argon are rather rough.

The Spectrum of R Cygni

Physical changes in long-period variable stars can only be completely understood by observing their spectra in as great detail as possible. These observations require the high resolution and dispersion attainable only with spectrographs attached to the greatest telescopes, such as those of Mount Wilson and Palomar Observatories. There Armin J. Deutsch and Ira S. Bowen have obtained spectrograms of the important variable R Cygni that show this star as undergoing some very unusual spectral phenomena during its light fluctuations.

Bright enough for many amateurs to observe, R Cygni is located near the 5th-magnitude star Theta Cygni. In an average period of 426 days, it changes from a mean maximum magnitude of 7.3 to a mean minimum of 13.9 and back again. Its greatest recorded brightness is magnitude 6.5, while it has appeared as faint as 14.2.

The majority of long-period variables are of spectral class *M*, but R Cygni is of the rare class *S*, characterized by bands of zirconium oxide (ZrO), as marked on the lowest spectrum of the accompanying exhibit prepared by Drs. Deutsch and Paul W. Merrill. The coude spectrograph of the 200-inch reflector was used, with dispersions of 18 and nine angstroms per millimeter (Sky and Telescope, October, 1957, page 577).

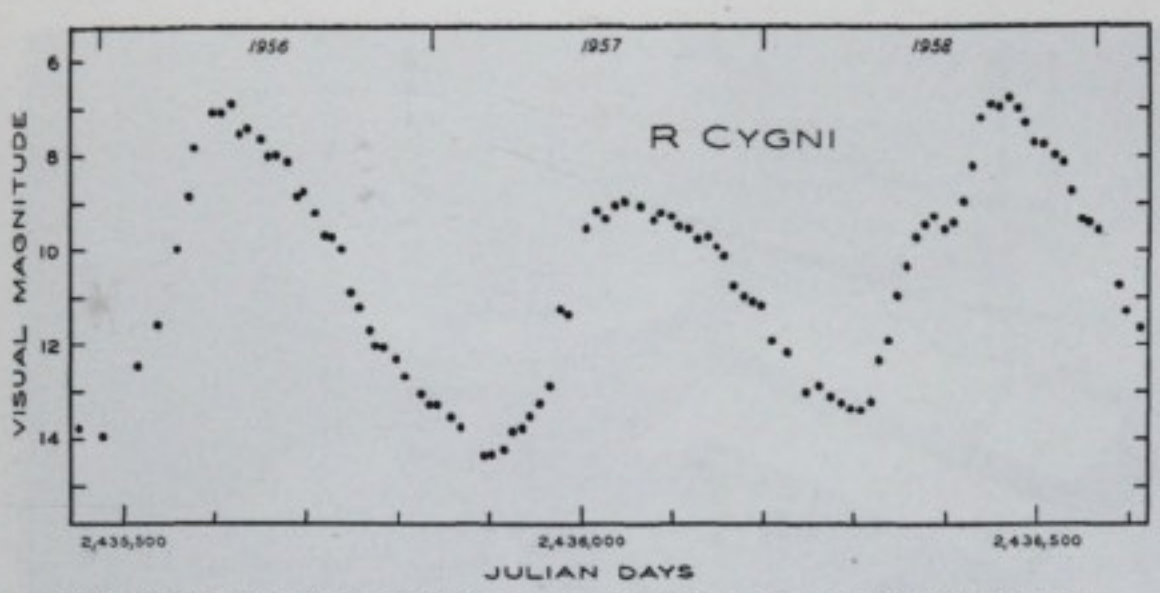
In each pair of spectra, the lower one was taken in 1957, when R Cygni's maximum brightness was about 1.7 magnitudes fainter than the average maximum, and the upper spectrum was taken in 1958, near a maximum 0.4 magnitude brighter than normal. Of the 1957 observations, **A** was secured one day after maximum, **B** 24 days before, while in 1958 the **X** spectrum was taken 18 days before maximum and **Y** 20 days after **X**. But since the spectrum of R Cygni changes very slowly during maximum, the marked differences between the sets of 1957 and 1958 spectra are characteristic of these two cycles of the star's light curve.

For example, it is evident from pair **I** that the zirconium-oxide bands were stronger in the first year than in the second, and all atomic absorption lines, such as neutral chromium (Cr I) in pair **II**, were much weaker. In general, the spectra show that the abnormally low maximum of 1957 was accompanied by a rich display of sharp emission lines. These were mainly subordinate lines of the metals, and they appeared in absorption at the 1958 maximum. Dr. Deutsch believes that the emission-line spectrum probably originated in a region of the star's atmosphere optically thick for the elements producing the lines and lying below a cooler absorbing envelope.

But there were exceptions to the general behavior. Absorption lines from the ground levels of the respective atoms are indicated above each pair of spectra, while emission lines from excited levels are indicated below each pair. Most of the excited-level lines that appeared in absorption in 1958 had appeared in emission in 1957 (displaced by about 10 kilometers per second to the violet), but this was true for few or none of the ground-level lines. Examples of the latter are the neutral cobalt (Co I) line and the two neutral vanadium (V I) lines between Co I and the iron line at 4347 angstroms, all in spectrum pair **III**.

Some emission lines of 1957 have intensities that correlate very poorly with the absorption-line intensities of 1958. In

These high-dispersion spectrograms of the long-period variable star R Cygni were obtained with the 200-inch telescope. Strips **A** and **B** were taken near the time of maximum light in 1957, and strips **X** and **Y** at corresponding times near the 1958 maximum. In the former year, the emission features of R Cygni tended to be much more conspicuous than in 1958. The labels above each pair of spectra indicate absorption lines, while emission lines are marked below each pair. Mount Wilson and Palomar Observatories photograph.



This light curve of the variable star R Cygni for the years 1956-58 has been derived by the American Association of Variable Star Observers. Each point is a 10-day mean of many observations by amateurs. The maximum in 1956 occurred on May 27th, in 1957 on August 8th, and in 1958 on September 23rd.

pair III, examples are the two V I lines (underlined) and two Cr I lines (marked by dots).

In the theoretical model of R Cygni proposed by Drs. Deutsch and Merrill, the emission lines are explained as the result of shock-heating of the star's atmosphere. The same shock waves also produce an appreciable outflow of matter from the star.

Andromedids Recovered

A famous November meteor stream that produced intense showers late in the 19th century, the Andromedids, has in recent years been listed as lost, presumably because severe planetary perturbations have changed the meteors' orbits so they no longer intersect that of the earth. Now, however, the stream has been recovered by G. S. Hawkins, R. B. Southworth, and F. Stienon at Harvard Observatory, in a study supported by the U. S. Department of Defense.

The Andromedids are one of two meteor showers associated with Biela's comet, which split into two parts that were last seen in 1852. The Andromedids were first observed on November 29, 1850, by Heis. This stream produced the intense meteor storms in 1872, 1885, and 1892, when the hourly rates were 3,000, 15,000, and 6,000, respectively. At each return the shower came at an earlier date because the node of its orbit is shifting westward. It was established beyond doubt that these meteors were moving in the orbit of Biela's comet, and were being perturbed by Jupiter.

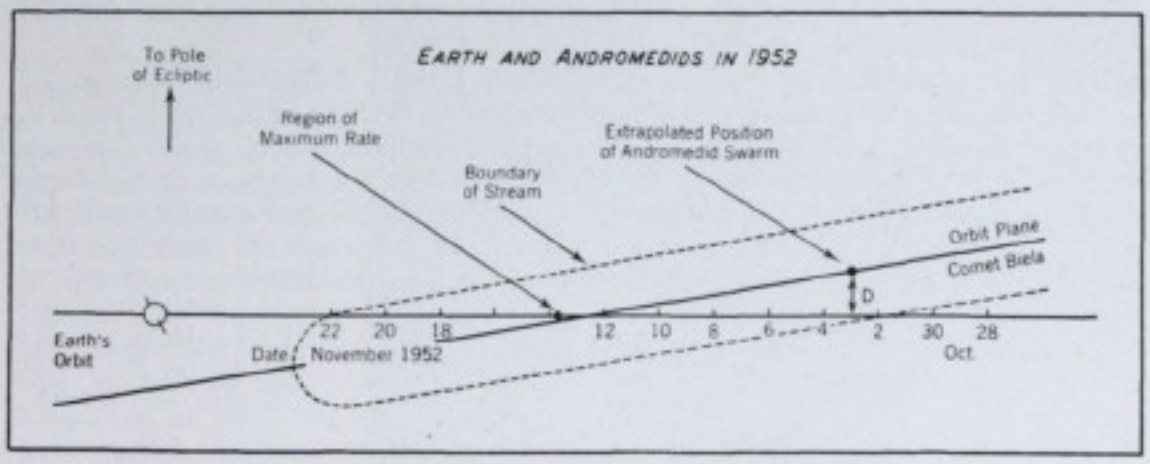
In the present century Andromedid observations are sparse. There was a weak return in 1904, and in 1940 an hourly rate of 30 was reported. By 1954, the English radio astronomer A. C. B. Lovell listed the Andromedids as a lost stream. But at about that same time, among the meteors photographed by Harvard patrol cameras in 1950, two were found by Fred L. Whipple to have orbits similar to the Andromedids.

Thus, in the belief that a vestige of the swarm still intersects the earth's orbit, Dr. Hawkins and his associates on the Harvard meteor program began a systematic search in the records of the super-Schmidt meteor cameras in New Mexico. For each November from 1952 to 1956, all meteors with radiants between 0° and 50° right ascension, and declinations 0° to 50°, were selected as suspect Andromedids.

From the period of Comet Biela, it was expected that Andromedids would have an observed velocity of 20 kilometers per second, and among the suspected meteors there was found a pronounced grouping of velocities between 19 and 21 kilometers per second. Further analysis indicated that photographic Andromedids occurred each year between November 2nd and 23rd, with a pronounced increase of activity on November 14th. In all, 23 members of the swarm were definitely identified and their orbits ascertained.

Since the Andromedid swarm in the 19th century had followed the comet's orbit closely, it could be assumed that planetary perturbations, especially by Jupiter, would be nearly the same in both cases. Thus, the changes in the orbital elements of the comet orbit were extrapolated to the present day. It was found that the major body of the swarm now passes between the earth and the sun, coming 1/50 of an astronomical unit from the earth's orbit at the closest point, or approximately two million miles away.

As the diagram shows, the earth passes directly below the swarm on November 3rd and cuts through the plane on November 14th, when the photographic rate reaches a maximum. At that time about one Andromedid per hour can be photographed, corresponding to a visual rate of about five meteors per hour.



This Harvard Observatory diagram by G. S. Hawkins shows the relation between the orbits of the earth and the Andromedid meteor swarm.

New Galactic Co-ordinates

OFTEN astronomers find it convenient to express the position of a celestial object not by right ascension and declination but by its galactic longitude and latitude — co-ordinates whose reference plane is that of the central line of the Milky Way, instead of the earth's equator.

As told in Otto Struve's article last October, the traditionally adopted position of the north galactic pole ($12^h\ 40^m$, $+28°$) is at least a degree in error. To decide on a better definition of galactic co-ordinates, the International Astronomical Union in 1955 formed a special Commission 33b, headed by the Dutch astronomer A. Blaauw. This group has now made its final report.

Henceforth, by international agreement, the north galactic pole is defined as lying at $12^h\ 49^m$, $+27°.4$ (1950 co-ordinates), and the new zero of galactic longitude is the great semicircle originating at the galactic pole in position angle 123°, with respect to the equatorial pole for 1950. Galactic longitude is counted from 0° to 360° eastward.

The IAU has decided that the symbols l and b be used for galactic longitude and latitude. When necessary to avoid ambiguity, the symbols l^I, b^I should be used for the old system, and l^{II}, b^{II} for the new one.

Zero longitude and zero latitude are to correspond to a point in Sagittarius practically coinciding with the galactic center, at $17^h\ 42^m.4$, $-28°\ 55'$ (1950). In old galactic co-ordinates, this point was longitude 327°.69, latitude $-1°.40$.

The new system was chosen to make its equatorial plane, which passes through the sun, as nearly parallel as possible to the plane of symmetry of the Milky Way system. The IAU will soon publish tables for the conversion of right ascension and declination into galactic co-ordinates and vice versa.

The 84-foot antenna that made contact with Venus dominates this aerial view of the Millstone Hill radar observatory at Westford, Massachusetts. The station is operated by Lincoln Laboratory, under U. S. Air Force sponsorship.

Radar Echoes from Venus

SINCE 1946, the reception of radio signals reflected from the moon has become a familiar experiment that has been performed by 10 different scientific teams in six countries. Obtaining radar echoes from the planets, however, is a far more difficult undertaking. To double the range of a radar installation means increasing the transmitted power 16-fold, or making the receiver correspondingly more sensitive. Even at their nearest, Venus is 110 times more distant than the moon, and Mars 145 times.

Successful radar contact with Venus on February 10 and 12, 1958, has recently been announced by the Lincoln Laboratory of Massachusetts Institute of Technology. The planet was about 28 million miles from the earth at that time. For both transmitting and receiving, the antenna used was the 84-foot radio telescope on Millstone Hill, near Westford, Massachusetts (also pictured last month on page 305).

In each experiment, the large paraboloidal dish was driven to follow the diurnal motion of Venus across the sky. A five-minute sequence of 4,100 pulses was transmitted at a frequency of 440 megacycles with a peak power of 265,000 watts. Of this power, about half a watt was intercepted by the tiny apparent disk of Venus, and only 10^{-21} watt was returned to the antenna. As the travel time for the two-way journey of the pulses was also about five minutes, the transmission ceased just before the echoes began to be picked up.

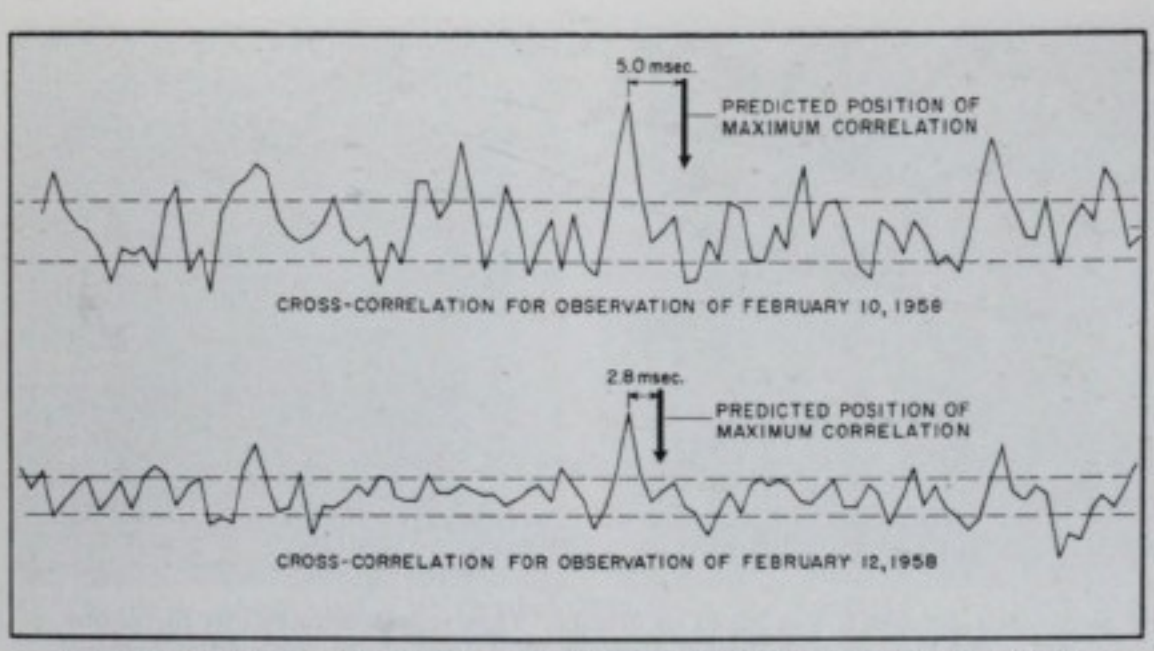
Most of the technical difficulty arose from the weakness of the returning signals. Success was possible only through the use of a solid-state maser to amplify them without adding appreciable noise (see *Scientific American,* December, 1958, page 42). The essential part of the maser was a small crystal of chromium-doped potassium cobalticyanide, mounted in a metal chamber that was supercooled by immersion in liquid helium. The radio energy was then further amplified by conventional vacuum-tube circuits, and recorded on magnetic tape for subsequent analysis.

The extremely weak signals reflected from Venus were nearly drowned in noise originating in the antenna and other components, as well as from cosmic sources. Because separate returned pulses could not be recognized, it was necessary to compare the tape recording with a recording of the transmitted signals, in effect trying various superpositions until the best fit was found. This matching process (known mathematically as cross-correlation analysis) required very extensive calculations on a high-speed IBM 704 digital computer. Once the most satisfactory fit was found, it gave proof that the echoes had actually been observed, and indicated the travel time.

For radio waves to travel from Millstone Hill to Venus and back took 295.5065 seconds on February 10, 1958, at 19:21:05 Universal time, and 302.9842 seconds on February 12th at 17:00:55. The uncertainty in each case was about ±0.0005 second, and the seven-second increase is fully accounted for by the change in the distance of Venus from the earth during the two-day interval.

The great importance of this kind of observational result is in providing the means for an extremely precise recalibration of our scale of distances in the planetary system. The *relative* distances of the planets from each other at any particular instant are very accurately known, so it is necessary only to measure one interplanetary distance directly in miles to get the scale factor. From earlier astronomical observations made by optical methods, the distance in miles of the earth from the sun is uncertain by several parts in 10,000, corresponding to more than 5,000 miles in an earth-Venus distance of 28,000,000. This uncertainty is reduced to only a few hundred miles in the radar work.

The Lincoln Laboratory investigators, headed by Robert Price and Paul E. Green, Jr., have not yet made a precise evaluation of the length in miles of the astronomical unit (the mean distance between the earth and the sun), but their preliminary calculations indicate that it may be about 0.0013 per cent smaller than the presently accepted value (corresponding to a solar parallax of 8.80 seconds of arc). So close an agreement indicates that no significant changes need be made in the figures of planetary distances and dimensions.


5.0 msec.
PREDICTED POSITION OF MAXIMUM CORRELATION
CROSS-CORRELATION FOR OBSERVATION OF FEBRUARY 10, 1958
2.8 msec.
PREDICTED POSITION OF MAXIMUM CORRELATION
CROSS-CORRELATION FOR OBSERVATION OF FEBRUARY 12, 1958

Each point on the curves represents a trial fit of the transmitted signals with the radar return, for different estimates of travel time. The highest peaks, indicating the best fits, are here compared with predicted times.

Future radar contacts with Venus may supply much detailed information about the planet itself, if improved techniques permit observing the returning pulses individually. It has already been found that Venus' surface is a better reflector of radio waves than the moon's. Dr. Price is confident that, at the frequency of 440 megacycles used, the reflection is from the body of the planet itself, and not from an ionosphere around it. The reflectivity could be determined numerically if single pulses were measured.

The shape of the pulses will be influenced by the rotation of Venus, as radiation returned from the approaching part of the disk should be shifted to higher frequencies, and that from the receding portion to lower ones. This is an illustration of the familiar Doppler effect. In addition, the roughness of the surface will affect the echoes. For example, if Venus were mirror-smooth, the echo would come only from a small area on the nearest part of its globe. On the other hand, we would receive radar energy from an entire hemisphere of a rough-surfaced planet. The time duration of a reflected pulse would be increased in the latter case.

Determining the rotation period of Venus from radar observations alone would be difficult, however, as a slowly rotating, rough planet would give echoes very similar to those from a rapidly rotating one with a smooth surface.

Clearly, the success already attained by the Lincoln Laboratory marks the start of an important if difficult new kind of planetary observing. Plans are being made for further contacts with Venus near inferior conjunction this September. Mars, a more difficult object because of its small size, will remain too distant during the next few years for effective radar observation with present equipment.

Robert H. Kingston of Lincoln Laboratory is holding the solid-state maser he designed and built for the Venus experiment. The sensitive crystal is inside the small cylinder at the left, from which wave guides run. The thermos flask contains liquid helium, used to cool the maser to its operating temperature of −456° Fahrenheit. The maser allowed high amplification of the radar echoes without adding appreciable noise. All illustrations with this article are courtesy Lincoln Laboratory.

QUESTIONS... FROM THE S+T MAILBAG

Q. What does the term *Atlas Coeli* mean?

A. This is the Latin equivalent of the English title, *Atlas of the Heavens*. The Latin title is retained from the original Czechoslovakian editions of the catalogue and atlases.

Q. In which constellation is the star Wolf 359?

A. This 13.5-magnitude star is in Leo, practically on the ecliptic, at right ascension $10^h\ 54^m.2$, declination $+7°\ 20'$ (1950 co-ordinates). It is 7.7 light-years distant from the sun; only the Alpha Centauri system and Barnard's star are nearer.

Q. How can I avoid a turned edge in polishing a mirror blank that already has a central hole?

A. A turned edge of negligible proportions would be produced at the perforation by using a subdiameter tool not much larger than the ring or *annulus* of glass. A more commonly adopted method is to insert a glass plug about 1/32-inch less in diameter than the hole. This plug is first ground to the same curvature as the mirror, then cemented in place with hot beeswax or paraffin. The mirror is then polished in the normal manner, after which the plug is removed.

Q. Has life ever been discovered in meteorites?

A. No. It is generally believed that the microorganisms that have been reported in meteoritic material contaminated it after it had fallen to the earth.

Q. Why is the magnification not given with astronomical photographs?

A. Magnification is an inappropriate term except where visual observations are involved. Instead, the plate scale, degrees per inch or seconds of arc per millimeter, is usually stated. It is greater for telescopes of longer focal length.

Q. Are there any cases where stars of the same spectral class have different colors?

A. Yes, when stars of very different intrinsic luminosities, such as giants and dwarfs of late spectral type, are being compared, but the actual color difference is relatively small. However, the light of a very distant star may be very much reddened by interstellar absorption.

Q. What is the difference between night glasses and ordinary binoculars?

A. It is essential for nighttime observing to have both great light-gathering power and a large exit pupil. The dark-adapted eye has a pupil diameter of about seven millimeters, so by definition (especially in military usage) night glasses have a 7-millimeter exit pupil, whereas day glasses have one of only five millimeters. For example, 7 x 50 binoculars may be called night glasses, and a 7 x 35 pair day glasses.

W. E. S.

In 1942 a unique set of stamps portraying astronomical subjects was issued by Mexico. They represent faithfully the photographic appearance of five celestial objects, as well as the Hertzsprung-Russell diagram. The three above, for regular postage, are left to right the Horsehead nebula in Orion, a total solar eclipse, and a spiral galaxy in Canes Venatici. The 2-centavo issue is violet and indigo, 5-centavo blue and indigo, and 10-centavo red-orange and indigo.

Northern lights appear on this deep blue Norwegian stamp of 1941, a semi-postal of 15 + 10 ore.

Some Astronomical Stamps—V

ALPHONSE P. MAYERNIK

THE POPULARITY of striking celestial sights as objects for postage stamp designs is recent, few if any stamps before the 1940's portraying comets, meteors, aurorae, or galaxies.

Among the earliest such stamps are the six issued by Mexico in 1942 to mark the opening of the astrophysical observatory at Tonanzintla, now a leading center for Milky Way research. Of the three at the head of this page, the left shows the famous Horsehead nebula near Zeta Orionis, a dark dust cloud silhouetted against a background of glowing gas. Next to it is a representation of the totally eclipsed sun, surrounded by the beautiful silver-gray corona. The third of these stamps portrays the great Whirlpool nebula, Messier 51, in Canes Venatici.

This remarkable object is a spiral galaxy, a remote counterpart of our own Milky Way system. It is a favorite deep-sky wonder of amateur astronomers, but a very large telescope is required to show its spiral form visually, while only long-exposure photographs with giant reflectors suffice to reveal fully its intricate glory.

Three other Tonanzintla commemorative stamps are on the facing page. The

These Russian stamps are all priced at 40 kopecks, the center one being issued in 1957 and the outer two in 1958. The ultramarine and yellow one (left) shows an aurora being recorded with a camera that covers nearly an entire hemisphere of the sky on a single exposure. The blue, black, and multi-colored commemorative (center) shows the Sikhote-Alin meteorite fall. On an indigo, light blue, and yellow postal (right), a bright fireball streaks above an observatory.

The three airmail stamps of Mexico's 1942 series: the Sombrero galaxy on a 20-centavo green and indigo issue; the planetary nebula in Lyra on a 40-centavo carmine and indigo; and the H-R diagram on a 1-peso orange and black. At latitude +19°, the Tonanzintla Astrophysical Observatory is strategically located for viewing the southern Milky Way. Its principal instrument is a 27-inch Schmidt telescope with a 31-inch mirror.

one at the left represents the spiral galaxy NGC 4594 in Virgo, seen nearly edge on, with a dark lane of obscuring material. In the middle is the famed Ring nebula in Lyra, a faint but beautiful smoke ring in amateur telescopes. Actually this object is a planetary nebula, a vast bubble of gas made visible by re-emitting radiation from the star in its center. Last of the series is a Hertzsprung-Russell diagram, a graph in which the luminosities of stars are plotted against their spectral types.

The varied and striking forms of the aurora suit it particularly for a pictorial theme. At the left of the facing page, a Norwegian stamp of 1941 shows the northern lights as a background for a fishing vessel. Beneath that stamp, a Russian issue pictures auroral draperies, together with an all-sky camera such as used by Soviet observers during the International Geophysical Year. Two other Russian issues deal with meteors. Of these the first marks the 10th anniversary of the fall of a great swarm of iron meteorites in the Sikhote Alin mountains of eastern Siberia, on February 2, 1947. This remarkable meteorite shower, known among Russian scientists as the "iron rain," has been described in considerable detail by E. Krinov in SKY AND TELESCOPE for May, 1956.

The other is a reminder of the importance of meteor observations during the IGY. A great fireball passes above an observatory dome, while in the foreground is an antenna used for radio detection of meteors.

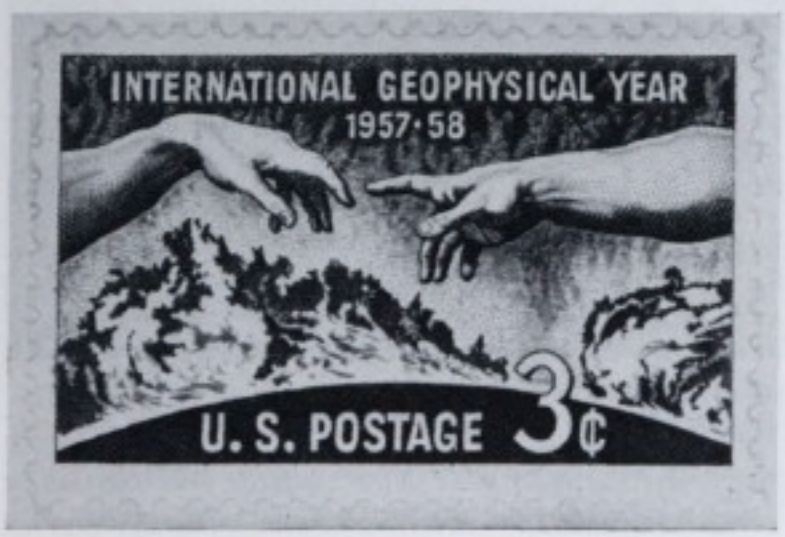
At the right, a French adhesive shows polar explorers on the march, beneath a striking auroral display. This symbolizes the French Antarctic expedition to Adelie Land, where important IGY studies of the aurora were made.

An American commemorative stamp at the foot of this page calls attention to the very extensive programs of solar observations forming part of the IGY. The view shows several spectacular eruptive prominences at the edge of the sun, great rapidly changing clouds of glowing gas. The dark segment below is not the sun itself but the occulting disk of a coronagraph.

The Yugoslav airmail stamp below carries, in addition to a schematic earth with artificial satellite orbits, a detailed representation of the first-quarter moon. As comparison with a lunar map will show, the features correspond fairly closely to the actual maria and craters on the moon's surface. With the growing popular interest in the moon, our natural satellite may be expected to occur more often on postage stamps throughout the world.

(To be continued)

Polar observations of the International Geophysical Year, including spectral studies of the aurora, are symbolized by this recently issued French stamp, a 15-franc dark gray-blue pictorial.



Solar prominences and hands from Michelangelo's "Creation of Adam" are on the 3-cent United States red-orange and black issue (left) of 1958. The detailed drawing of the lunar surface on the 300-dinar blue Yugoslavian airmail (right) indicates the growing interest in astronomical objects.

Amateur Astronomers

Many Amateurs Register for National Meeting

NEARLY 200 persons have already signed up for the Nationwide Amateur Astronomers Convention in Denver, Colorado, August 28-31. It will mark the first time that amateurs from all parts of the country have gathered for a general meeting.

Embellishing the regular program of papers and banquets are three field trips. The first, on Friday, August 28th, is to the National Bureau of Standards laboratories in Boulder (page 304, April). Another is scheduled for the Air Force Academy at Colorado Springs (page 250, March issue).

The third trip will take place on September 1st, the day following the formal meetings, since eight hours are needed to complete the 200-mile round-trip bus drive to Climax, Colorado. There will be an inspection of the facilities at the High Altitude Observatory of the University of Colorado, pictured here.

Primarily a solar observatory, this station is at an elevation of 11,200 feet, in the Rocky Mountains not far from Leadville. The two main solar instruments are 5-inch and 16-inch coronagraphs. Also in use is the K-coronameter, which observes the sun's tenuous white-light corona electronically by recording the intensity of polarized light.

For planetary work, there is a spectrograph constructed especially for detection of possible auroras on Venus. This instrument was used by Gordon Newkirk, Jr., for his observations of Venus' ashen light (see page 368).

Charges for all of the field trips were given on page 324 of last month's issue. Each trip will be made by chartered bus only.

Since May 1st, the registration fee for the convention has been increased to $2.50 per person and $3.50 for a family. Remittances should be sent to Ned Onstott, 2421 Second Ave., Pueblo, Colo., who will also accept room and field-trip reservations.

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Denver 23, Colo.

THIS MONTH'S MEETINGS

Albany, N. Y.: Albany Amateur Astronomers, 8 p.m., Dudley Observatory. May 11, Charles Griggs, Jr., "Saturn and the Outer Planets."

Baltimore, Md.: Baltimore Astronomical Society, 8 p.m., Enoch Pratt Library. May 18, Dr. John Strong, Johns Hopkins University, "Uses of Balloons for Meteorological and Astrophysical Observations."

Cambridge, Mass.: Bond Astronomical Club, 6:30 p.m., Coach Grille. May 7, Dr. Hari K. Sen, Air Force Cambridge Research Center, "Above and Beyond."

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. May 8, Dr. Leona Marshall, Enrico Fermi Institute, University of Chicago, "Magnetic Field in Space."

Edinburg, Tex.: Magic Valley Astronomical Society, 8 p.m., science building, Pan American College. May 22, Rev. Robert E. Fishburn, "Beginning of Guided Missiles."

Lemont, Ill.: Argonne Astronomy Club, 8 p.m., chemistry building, Argonne National Laboratory. May 22, Dr. Ben H. Wilson, "Midwest Meteorites."

Madison, Wis.: Madison Astronomical Society, 8 p.m., Washburn Observatory. May 13, Prof. George Woollard, University of Wisconsin, "Some of the Results of the International Geophysical Year Measurements in the Antarctic Ice Sheet."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. May 20, motion picture, The Strange Case of the Cosmic Rays.

New York, N. Y.: Junior Astronomy Club, 2 p.m., main building, New York University. May 2, William H. Glenn, "Planetary Observing."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. May 2, Timothy P. McCullough, Naval Research Laboratory, "Progress in Radio Astronomy."

LEXINGTON, KENTUCKY

The recently organized **Bluegrass Astronomical Society** has joined the Great Lakes Region of the Astronomical League. The club has 21 adult members and a separate division for its 10 juniors. Interested persons should communicate with Joseph C. Hayden, 336 Colony Rd., Lexington, Ky.

On September 1st, many participants in the nationwide convention of amateur astronomers will visit the Climax observing station of the High Altitude Observatory. The station is on the continental divide about 100 miles west of Denver, Colorado. The dome at the left houses a 26-foot equatorial spar, on which are mounted a K-coronameter and a planetary spectrograph. At the far right is the building of the 5-inch coronagraph used for daily solar observations; it also contains a flare-patrol instrument and a spectrograph. University of Colorado photograph.

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OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

Sketching a Sunrise Eclipse

THE TOTAL ECLIPSE that occurs on October 2, 1959, will present only a brief interlude during the sunrise hour, with totality lasting less than a minute for observers in eastern Massachusetts and southern New Hampshire. Everywhere the sun will rise at or near full eclipse; even along the coast the total phase will take place when the sun is only a degree or two above the sea horizon.

While these hardly are favorable conditions for most kinds of scientific studies, the reverse is true for sketching scenic effects. The lower the elevation of the sun, the more pronounced are the color effects associated with this awesome spectacle.

Those who plan to sketch or paint the event should select, far in advance, an appropriate setting with an unobstructed sunrise view. Distant very low hills, trees, an isolated house, a barn, and especially a body of water will enhance the picture, accentuating the eerie aspect of shadow and shade present only at a total solar eclipse.

After a favorable locale has been chosen and the scene toward the east sketched, the field of perspective should be marked off in squares or otherwise broken into subdivisions suitable for noting quickly and briefly the important features of the scene. Remember that darkness during totality will preclude actual application of the color selections, and the time will be so brief that only notes can be taken.

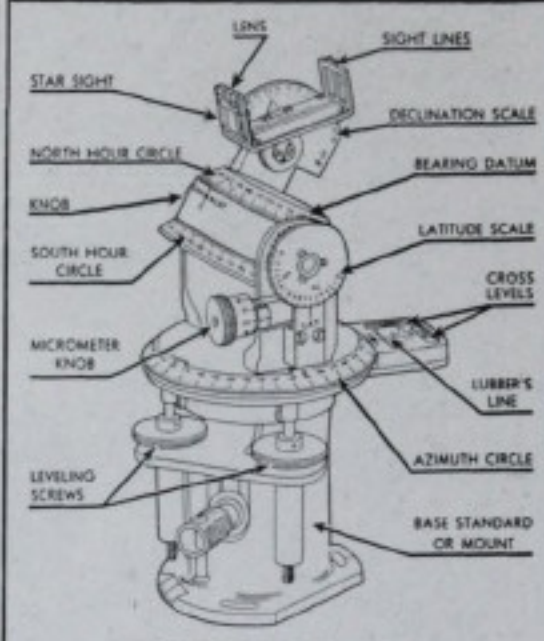
In one brief minute the artist will have to note the outline and color of the sun's corona, the shadow and color values of the sky close to and farther from the sun, the horizon effects, the lighting of the landscape, the foreground shadows, all of them changing completely and drowned out by the first brilliant rays of sunlight as soon as the moon "shutter" starts to move off the sun.

Have at least two or three full-scale rehearsals immediately before eclipse day. Knowing what to look for and where it belongs on the sketch will insure more accurate recording of shade and color values, grasped instinctively and without obvious conscious thought that could detract from subconscious impressions. The rehearsal sketches will be of value also for comparison with the final one of eclipse day.

The visible outline and brilliance of the sun's corona, the depths of shade and coloring in the sky, will all depend upon atmospheric conditions. There will be some variation between the horizon effects and those of the middle distance and foreground. A body of water, trees, and clouds all affect the tones of shade and color. Each landscape will present its own problems, to be determined as far as possible during the sunrise rehearsals.

In early October in New England, autumn foliage is at its most colorful stage, and clear skies are the rule. For the land-

This water-color sketch by Lewis Lindsay is a typical guide layout prepared in advance, showing the general appearance of the eclipse scene, but with only approximate tonal values from rehearsal observations. The moon's black disk and the corona are of exaggerated size, matching the visual impression for objects so close to the horizon.



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(Left in photo) B & L, 6-inch, f/6.3, 93° wide-angle aerial camera lens in Fairchild lens cone. Built-in haze filter and diaphragm. Lens will cover up to 8 x 10 film. Original cost $1,000.00. With case, only $39.50 postpaid.

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(Right in photo) We don't know where or how these were used. Product of E. A. Laboratories. 91.44 mm., f/1.9 lens in 2⅜" mount. Postpaid. May be used for telescope, camera, enlarger, etc.

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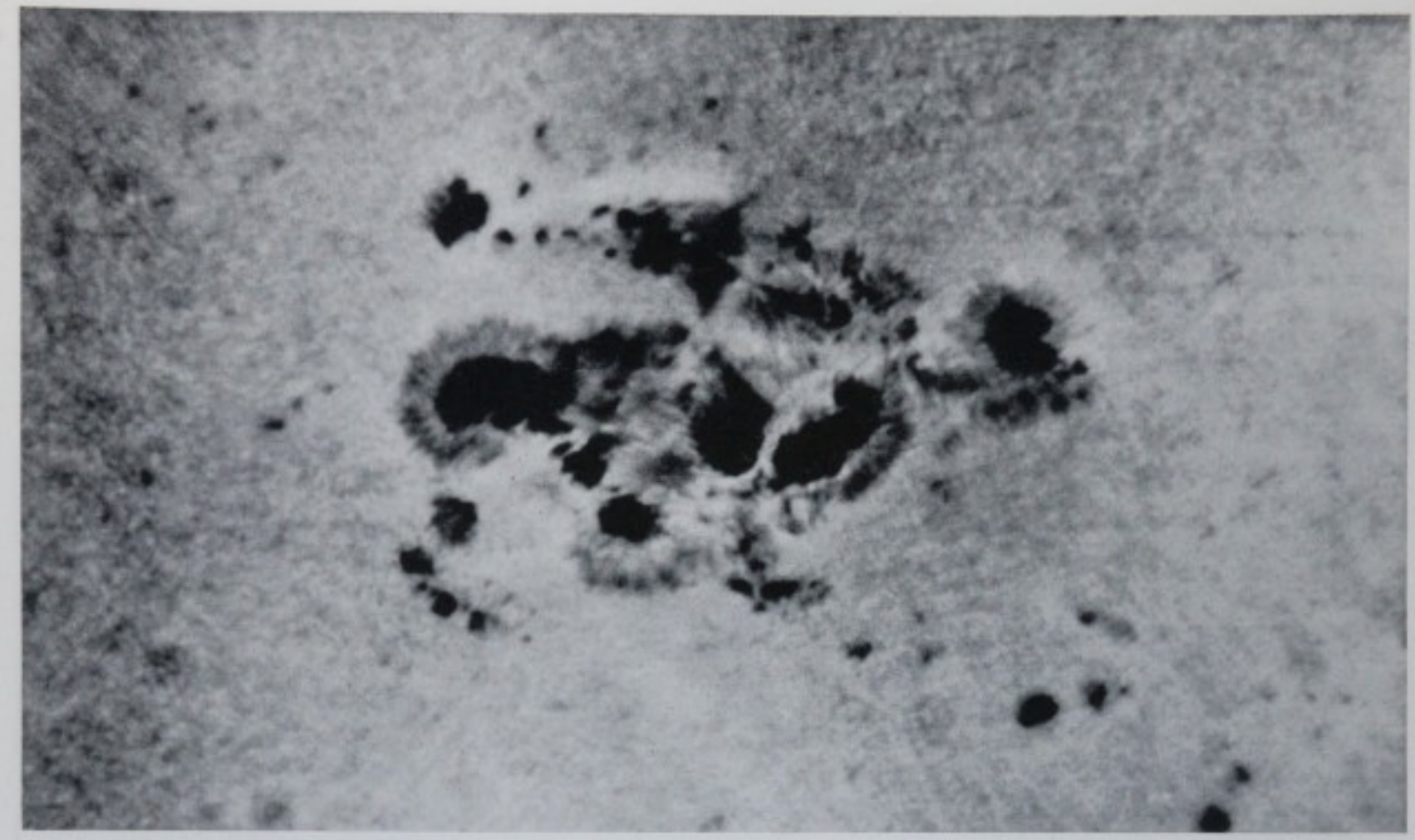

MAGNIFICENT PERFORMANCE

The elusive solar granules are now being photographed day after day from sea level with a 3.5-inch Questar.

This exposure was made at midday, March 15th, right through the entire earth's atmosphere, and with the sun still far from zenith, at the home of the Ralph Davises in Sarasota, Florida. You may judge the size of detail photographed by comparing it with the largest granules, which are 2 seconds in diameter.

We think much of Questar's success in achieving these phenomenal pictures is due to its lack of internal tube currents. In this shortest of all telescopes, where lens and mirror are separated by but 6 inches, there is scarcely room for a current to get started. The effective focal length used here was over 50 feet. The photographic print fails to show all of the beautiful intricate tracery so plainly seen in the sunspot on the negative.

At left is our new full-aperture solar filter, for those who want the highest resolution visually. Like the small version, which comes with every Questar, it keeps most of the harmful solar rays outside the instrument where they belong. Four separate evaporations of chromium are used to avoid pinholes. After each deposit, the coat is vigorously rubbed. The work is done for us by Evaporated Metal Films Company of Ithaca, New York. The glass itself, which must be plane-parallel to about 1 second, is only 0.080-inch thick and is made by optical contacting to a heavier flat, thus avoiding awkward weight and thickness.

At lower left is a full-aperture filter in its handmade walnut case, while another is attached to the telescope's barrel, in profile here, to show the 6 radial slots of its ventilated cell. This filter may be used with any telescope. Price $150.

Questar costs only $995 complete in English leather case; with quartz mirror $1100. Literature on request.

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345 Belden Ave., Chicago 14, Ill.

scape painter, however, a clouded or partially obscured eclipse need not signify failure. Clouds may accentuate the phantasmal beauty and deepen the aspect of unearthliness. Furthermore, any attempt at sketching will provide valuable experience for future eclipses.

An effective painting of a solar eclipse is an artistic achievement that no form of photography or mechanical technique can simulate or approach.

LEWIS LINDSAY
San Francisco, Calif.

SUNSPOT NUMBERS

The following American sunspot numbers for February have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

February 1, 107; **2**, 118; **3**, 133; **4**, 155; **5**, 109; **6**, 103; **7**, 63; **8**, 66; **9**, 83; **10**, 96; **11**, 114; **12**, 78; **13**, 102; **14**, 77; **15**, 120; **16**, 104; **17**, 169; **18**, 115; **19**, 112; **20**, 111; **21**, 135; **22**, 142; **23**, 172; **24**, 151; **25**, 142; **26**, 172; **27**, 152; **28**, 129. Mean for February, 118.9.

Below are mean relative sunspot numbers for March by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations in Locarno and Arosa.

March 1, 158; **2**, 144; **3**, 137; **4**, 145; **5**, 133; **6**, 138; **7**, 139; **8**, 140; **9**, 149; **10**, 151; **11**, 135; **12**, 126; **13**, 159; **14**, 173; **15**, 216; **16**, 225; **17**, 228; **18**, 230; **19**, 242; **20**, 236; **21**, 215; **22**, 200; **23**, 194; **24**, 178; **25**, 199; **26**, 195; **27**, 178; **28**, 171; **29**, 217; **30**, 227; **31**, 244. Mean for March, 181.4.

DEEP-SKY WONDERS

POLAR SKIES, though seldom mentioned in this column, have a great deal to offer the observer, especially if he is fond of galaxies. This month we turn our attention to Draco, and to five objects that should be within the reach of keen-eyed users of fair-sized telescopes.

At right ascension $12^h\ 16^m.6$, declination +75° 26′ (1950 co-ordinates), is the 5th-magnitude star 5 Draconis. Near it, almost in the same field, are three small faint galaxies discovered by William Herschel, NGC 4291, 4386, and 4319. NGC 4291 (labeled 275[1] in Norton's *Star Atlas*) lies at $12^h\ 18^m.1$, +75° 40′, and is 12th magnitude. Though very tiny, 0′.3 by 0′.3 in extent, it is still easy to distinguish from a star.

NGC 4386 (277[1] in Norton's) is at $12^h\ 22^m.4$, +75° 48′, and is about the same size as 4291 but appears slightly fainter. At least a whole magnitude fainter than these two is NGC 4319 (276[1]), lying between and somewhat south of the pair. To see all three galaxies is a feat.

Farther south, near Kappa Draconis, is NGC 4236 (263[1]) at $12^h\ 14^m.3$, +69° 45′. It is a large 12th-magnitude Sc spiral, 23′ by 6′. Nearby is NGC 4128, $12^h\ 06^m.1$, +69° 03′, an Sa spiral of the same bright-

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S508A	Ecliptic-based star map — with equatorial grid and names
S508	Ecliptic-based star map — with equatorial grid, **without** names
S508B	Ecliptic star map list — positions and magnitudes for 224 stars
S505	Nine-inch protractor on paper — for planet orbit drawings
S511	Inner planet chart — orbits of Mercury, Venus, Earth, Mars
S512	Outer planet chart — orbits of Mercury to Saturn
S501A	Special rectangular co-ordinate paper — for star maps
S502	Polar co-ordinate paper — for circumpolar star maps

Price for each item listed above: 1 to 9 sheets, 10 cents each; 10 to 24 sheets, 8 cents each; 25 to 99 sheets, 6 cents each; 100 or more, 5 cents each.

From Stetson's *Manual of Laboratory Astronomy*, the following chapter is available as a separate booklet, at 50 cents each: I, Star Chart Construction.

SPECIAL: DC5 — Large wall chart of the Draper spectral classes, printed in four colors and mounted on canvas. Limited quantity. (Slightly damaged along edges.) **$14.00 each**

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Cambridge 38, Massachusetts

ness but 2′ by 0′.5. It is not shown in Norton's, though plotted, unlabeled, in the Skalnate Pleso *Atlas of the Heavens*.

Bagging all five of these objects will take a good telescope, dark and transparent skies, and probably some effort because "landmark stars" are so few there in Draco.

WALTER SCOTT HOUSTON
Rte. 3, Manhattan, Kans.

NEW BRIGHT VARIABLE STAR

A new Algol-type variable star, bright enough to be watched by amateurs with binoculars, has been discovered by W. Strohmeier on patrol photographs taken at Remeis Observatory, Bamberg, Germany. The 1950 co-ordinates of this star, provisionally named Bamberg Variable 224, are $1^h\ 28^m.9$, $+53°\ 46'$; it is south and east of Theta Cassiopeiae.

The visual magnitude at maximum is about 7.8. Every 3.7 days, the star fades in about five hours to magnitude 9.0 and takes the same length of time to recover its full brightness. A minimum is scheduled for May 1, 1959, at 4^h Universal time; other minima can be predicted by adding multiples of the period, 3 days 16 hours 30.2 minutes.

Dr. Strohmeier reported the variability of this star (also known as BD +53° 323 and HD 9234) in *Minor Publications* Nos. 24 and 25 of Remeis Observatory.

Walter A. Feibelman, Pittsburgh, Pennsylvania, photographed the recent auroral display on March 28th, at 9:36 p.m. Eastern standard time.

MARCH'S FINE NORTHERN LIGHTS

CONSPICUOUS auroral activity on three nights running, which culminated in a major display on the night of March 28-29, was widely observed.

On the evening of March 26th, Herbert Miller, Enumclaw, Washington, saw a bright aurora, which at 8:30 p.m., Pacific standard time, consisted of a homogeneous arc 20 degrees above the northern horizon. Between 9 and 9:30 the display was at its height. Huge waves of light moved up the northern sky to the zenith, where several large rays formed a pale white corona. About this same time, there were vivid red and pale green rayed arcs in the north. Clouds halted Mr. Miller's obser-

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vations. A flaming aurora was also seen at Leavenworth, Washington, by Stuart and Stanley Emig.

The same auroral storm was witnessed at Appleton, Wisconsin, by Tom Van Heuklon, who reported that at midnight the whole northern sky was covered to the zenith, and at times streamers reached past the celestial equator.

The weak aurora of the following night was seen by Steve Brenner and Josef R. Otoupalik, Greeley, Colorado, and by Walter A. Feibelman at Pittsburgh, Pennsylvania.

On March 28th, a much stronger aurora was seen by Mr. Feibelman under good sky conditions. A very stable and quite narrow arc lasted from 8:15 p.m. to 9:30 Eastern standard time, when it broke up and narrow bright rays formed. Very rapid development ensued, with waves of a flaming aurora starting at 9:39. By 10 p.m. there was only a diffuse glow, but at 11 o'clock another arc and rays formed. A weak display persisted until dawn.

Others who have submitted reports of these spectacular displays are Kenneth J. Delano, Baltimore, Maryland; John Loudenberry, Phillipsburg, New Jersey; Herbert A. Luft, Oakland Gardens, New York; Joseph A. Keane, Schenectady, New York; Robert Zappala, Cleveland, Ohio; Ron Koczor, Ft. Wayne, Indiana; Richard Salisbury, Midland, Michigan; Thomas L. Immel, Willmar, Minnesota; Pierce F. Flamm, Cincinnati, Ohio; Lewis Dewart, Sunbury, Pennsylvania; Theodore Kaplits, Massapequa, New York; and the Montreal Centre of the Royal Astronomical Society of Canada.

VARIABLE STAR OBSERVING DOWN UNDER

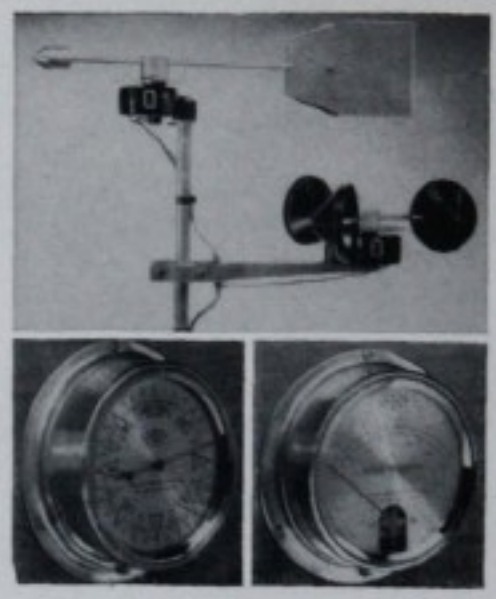
One of the most active of Southern Hemisphere amateur observing groups is the variable star section of the Royal Astronomical Society of New Zealand. Under the leadership of Frank M. Bateson, its members make regular visual observations of the brightness of southern variables. The results are published at frequent intervals in the section's *Circulars*.

Hitherto, variable star observing in the far southern sky has been handicapped by lack of charts for many telescopic fields. The New Zealand organization is actively engaged in preparing suitable maps. Recently Mr. Bateson published a 27-page booklet with detailed instructions for variable star work, containing much useful information.

Southern Hemisphere amateurs who are seriously interested in taking part in the section's observing program should write to A. F. Jones, 40 Trafalgar St., Timaru, New Zealand.

CORRECTION

Kurt Weis, of New York City, points out that the lunar eclipse of May 13-14, 1957, mentioned on page 269 of the March issue, was total rather than partial.



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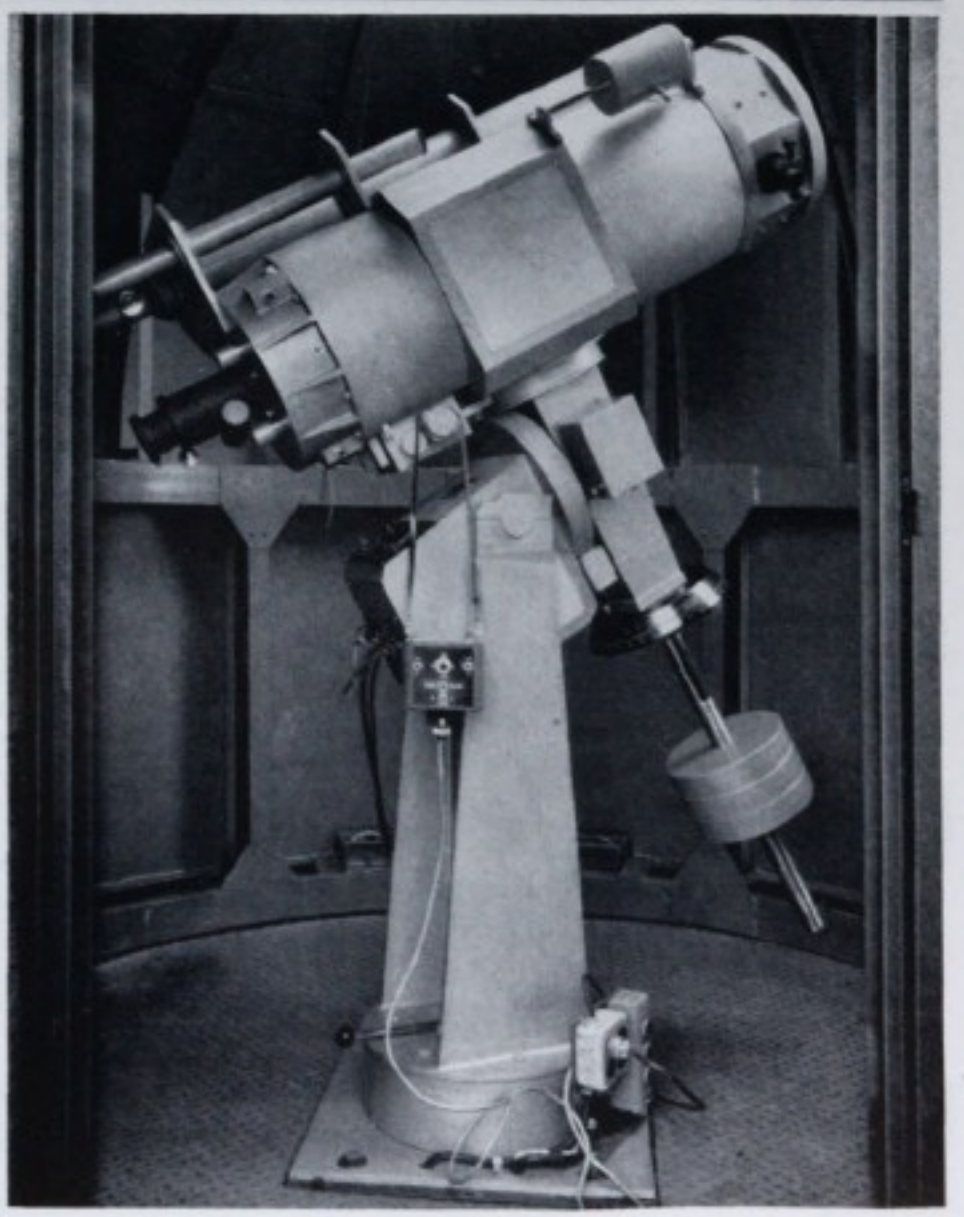
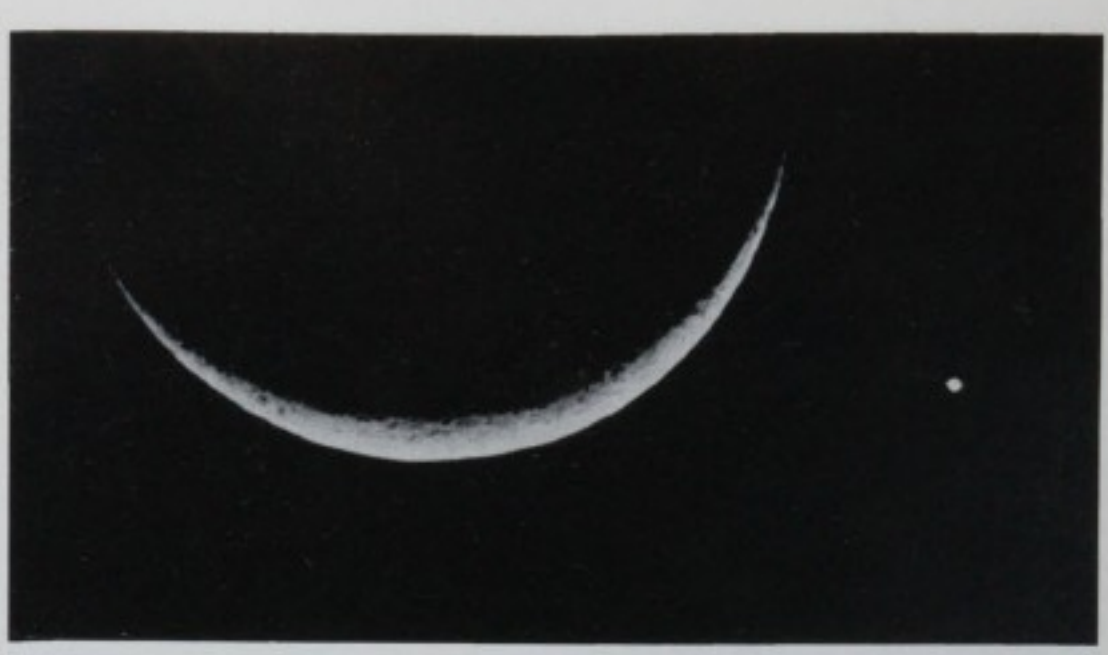


The lights of Ft. Worth, Texas, are in the foreground of this picture of Venus and the moon taken by Burton G. Ford. Exposure was one second on Super Panchro Press film. Earthshine on the moon's dark part can be seen.



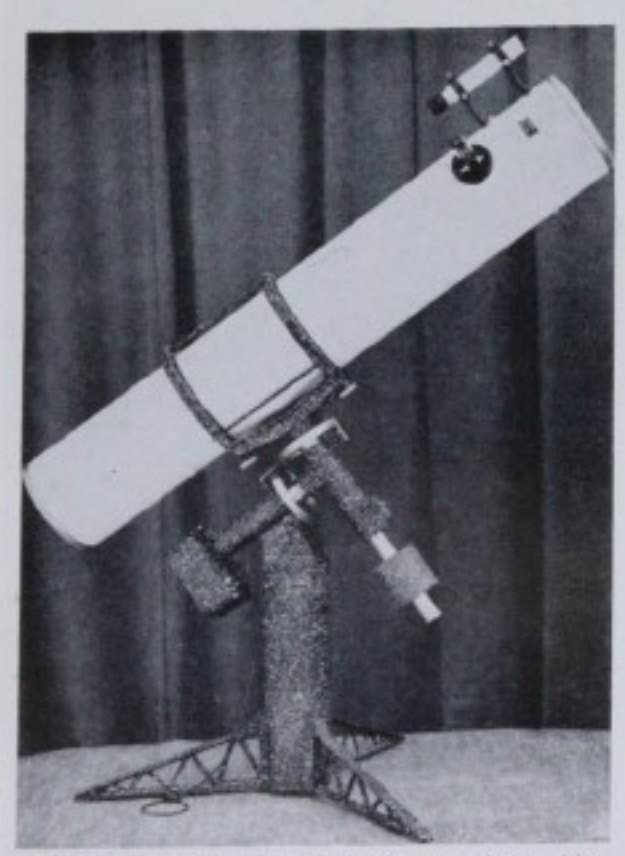
Mr. and Mrs. Bradford A. Smith photographed the crescent moon and gibbous Venus (right) at 2:05 Universal time, using 103-F emulsion, 1/5-second exposure, and development for 2½ minutes in D-19.

March Conjunction of Venus and the Moon

DURING the early evening of March 11th, the brilliant planet Venus and a slender crescent moon formed a close and beautiful pair in the western sky. Lower in the heavens was the planet Mercury, which the moon had passed just a day before. The configuration of the moon and Venus was very widely observed in North America, and proved a popular subject for photography.

Of those who sent pictures to this magazine, Ed Pankow of Maywood, California, used a 6-inch reflector to photograph Venus and the moon. At State College, New Mexico, Bradford A. Smith and his wife took several pictures with a 12-inch Newtonian telescope, and one of these is reproduced here. Burton G. Ford, Ft. Worth, Texas, secured the horizon view of the spectacle, at the left, with a 4-by-5 Speed Graphic camera fitted with a 10-inch lens.

ASTROLA Reflecting Telescopes



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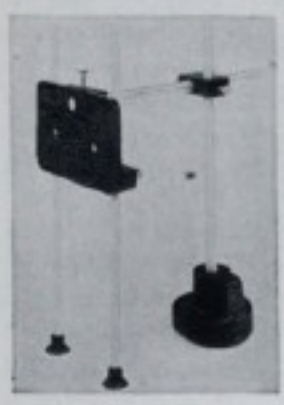

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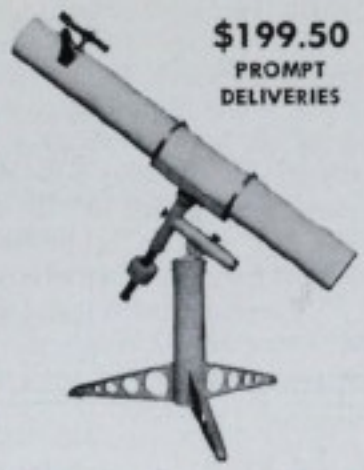

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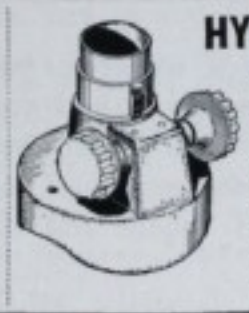

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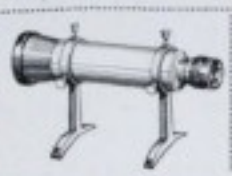

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BOOKS AND THE SKY

HANDBUCH DER PHYSIK, VOL. 51 ASTROPHYSICS II: STELLAR STRUCTURE

S. Flügge, editor. Springer-Verlag, Berlin, 1958. 831 pages. DM 175.

THIS, the second of five volumes on astrophysics, is almost twice as large as Volume 50, reviewed in SKY AND TELESCOPE for February, 1959, and, unlike its predecessor, is mostly in English. There are, however, subject indexes in both German and English, and one in French for E. Schatzman's contribution on white dwarfs.

M. H. Wrubel's chapter on stellar interiors is the same type of excellent summary in this field as was D. Barbier's chapter on stellar atmospheres in the preceding volume. Moreover, it is a worthy successor to S. Chandrasekhar's discussion on the structure of stars, to be found in J. A. Hynek's *Astrophysics*. An observational astronomer interested in interpreting the color-magnitude diagram of a star cluster, for example, will find Wrubel's treatment most useful. The theoretical study of stellar interiors has been stimulated in recent years both by observations of clusters and by the development of high-speed computers to handle the detailed and complex integrations. Although one can confidently predict great strides in the coming years, it is probable that theory will, for the most part, *follow* observation in the immediate future.

We are, as Wrubel points out, "still a far cry from treating the problem [of stellar interiors] in its most general form," and theoretical conclusions must be taken with a grain of salt. We need surer knowledge of the energy-generating processes, as well as improved theories of convection, pulsation, and magnetohydrodynamic phenomena. There is much to be done. For instance, we do not have even an approximately good model for either Cepheid variables or blue dwarfs.

The Hertzsprung-Russell diagram, probably the most useful correlation in astronomy, is the subject of H. C. Arp's chapter. In the diagram's original form, absolute magnitude was plotted against spectral type. But, because of the speed and accuracy with which color indices can now be measured, these are often substituted for spectral type.

Practically all of Arp's references are to work in this country, where the excellent skies in California and the Southwest have stimulated photoelectric researches. More than half of this chapter deals with the photometry of galactic and globular clusters, a field in which Arp himself has made substantial contributions.

Two illustrations are of particular interest. On page 76 the many relationships between the H-R diagram and other fields of research are shown schematically; and on page 93 there is a color-magnitude array for 171 stars nearer than 20 parsecs, based on data compiled by R. H. Stoy. It should be borne in mind, however, that this list is only about 10-per-cent complete, and the final picture will be significantly changed when colors have been determined for the missing stars, the great majority of which are red dwarfs. Two red stars that lie about five magnitudes above the main sequence are misplots.

The 162-page discussion of stellar evolution by G. R. and E. Margaret Burbidge is another important, stimulating, and timely contribution to the literature. Their approach has intentionally been somewhat nonselective, with the result that 480 references are given, half of which have been published since 1953. O. Struve discussed this chapter in some detail in the March, 1959, issue of this magazine (page 240), and reached the conclusion, "The time is not quite ripe for an astronomical *Origin of Species*." This is undoubtedly because we do not as yet have enough *factual* information about the stars.

Two questions are involved: What information? What stars? It is apparent that a selection must be made, for with a moderately large reflector an astronomer can work photoelectrically on any of more than a hundred million stars. Obvious choices include stars in galactic and globular clusters, supergiants, and Cephe-

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The Book was reviewed in the January issue of SKY AND TELESCOPE.

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ids; but there are assuredly stars that, though they are key pieces in the evolution puzzle, have not yet been identified as such.

It is pertinent, in this connection, to consider how large a sample of the brightest stars can be observed with highest accuracy in a variety of ways, and in a reasonable length of time. My guess is that, given the proper telescopes and instrumental and computational accessories, exceptionally accurate spectral and luminosity classifications, magnitudes in several wave lengths, photometric distances, space velocities, and chemical compositions could be garnered within 10 years for at least 100,000 of the brightest stars. Until these data become available – together with observations of selected fainter stars – it will probably be impossible for a modern Darwin to write an astronomical *Origin of Species*.

The literature of stellar evolution is full of speculation, blind alleys, and wrong or misleading conclusions – perhaps it will always be. But now it seems possible, for the first time, to build up quickly a substantial body of factual data for the bright stars which will guide future speculations along more realistic lines.

The fundamental problem of the cosmic abundances of the elements is taken up in two shorter chapters, by H. E. Suess and H. C. Urey on the planets and meteorites, and by L. H. Aller about the sun and stars. Determining these abundances is a long and difficult process, but there are far-reaching implications in such results as the hydrogen-helium-metals ratios; the dearth of lithium, beryllium, and boron; the abundance maximum at the atomic weight of iron; the presence of technetium in *S* stars; isotope abundances; and the differences in composition from star to star.

A. J. Deutsch's section on stellar magnetic fields deals with a subject so new that it would scarcely have been considered 15 years ago. He summarizes his ingenious and difficult analysis of the variations in radial velocity, equivalent widths, and magnetic fields, which leads to a detailed map of the surface of a spectrum variable star. E. Schatzman's chapter on the theory of white dwarf stars will serve as a useful introduction to his book on these strange but numerous objects.

Almost half of Volume 51 is devoted to variable stars, from both the observational and theoretical viewpoints. The total number of variables is impressive, but their proportion to other stars is small. Nevertheless, no other group of stars has awakened more interest among professional and amateur astronomers alike, nor provided more important information. If John Goodricke were with us today, he would be amazed at how the Algol variables have supplied vital facts concerning stellar masses, radii, densities, temperatures, rotations, atmospheres, and interiors, while the Cepheids have made it possible for us to measure distances as large as 10^{22} miles with some confidence. Amateurs, to whom variable stars have been of special interest, would benefit greatly from new techniques and instruments; unfortunately, far too few amateur telescopes have been equipped with photoelectric photometers.

The 252-page chapter on variable stars by P. Ledoux and T. Walraven is a book in itself and will repay detailed study. Walraven's beautiful continuous light curves of the RR Lyrae-type variables AI Velorum and SX Phoenicis are especially thought-provoking. A wide variety of problems concerning Cepheid types, colors, and amplitudes are discussed. This field is so active that substantial progress has been made since this chapter was written. Much space would be required to do justice to this new and needed addition to the literature.

Ledoux is also author of a shorter chapter on stellar stability, in which he considers the effects of rotation, magnetic

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Professor Drecker's library (offered only with the sundial collection) consists of 339 books and pamphlets on gnomonics, including Regiomontanus' *Calendarium* of 1483 and many valuable 16th- and 17th-century works.

Inquiries from responsible persons are invited.

PLANNING AND RESEARCH ASSOC.
45 Bromfield Street, Boston 8, Mass.

Again in Print!

Shapley-Ames CATALOGUE OF BRIGHT GALAXIES

"A Survey of the External Galaxies Brighter than the 13th Magnitude" gives NGC number, 1950 position, magnitude, size, and type for 1,249 objects.

This publication (Vol. 88, No. 2, of the Harvard *Annals*) was out of print for some time, but is now available in an offset-printed edition.

$1.50 postpaid

Order directly from

HARVARD COLLEGE OBSERVATORY
Cambridge 38, Massachusetts

fields, and external gravitational forces. He concludes that, with accepted laws of energy generation and reasonable stellar models, ordinary stars are thoroughly stable, and that it is still uncertain what kind of instability is responsible for the oscillations of Cepheids and other intrinsic variables.

Mrs. C. Payne Gaposchkin has contributed an excellent short introduction to the novae, which will probably stimulate many readers to delve into her recent book on the subject. The study of these strange and cosmologically important objects has recently taken a surprising turn because of Merle Walker's key discovery that one of them, DQ Herculis, is an eclipsing binary. This chapter and F. Zwicky's on supernovae were, to me, the best in the book in having the most exciting material per page. The history of supernovae gives food for thought. Although much of the recent work has been done at Palomar and Mount Wilson, many significant contributions have been made by astronomers with small telescopes or no telescope at all. Strangely enough, we still do not have a good multicolor photoelectric light curve for any supernova, although this would certainly provide some information on the energy-generating processes involved.

JOHN B. IRWIN
Goethe Link Observatory
Indiana University

Read This Advertisement

Here is a combination of a Barlow and a particular ocular which gives outstanding results. It consists of our new Barlow and our 16.3-mm. (⅝" focal length) Erfle eyepiece. While the Barlow was not specifically designed to work with this eyepiece, it does so to an astonishing degree. All images are sharp and hard to the very edge of the field.

The Barlow gives magnification up to slightly over three times that of the ocular alone. It is achromatic, coated, and mounted to the U. S. standard size of 1.250 inches.

The modified Erfle eyepiece has a field of 75 degrees with excellent eye relief. The combination gives the equivalent focal length of slightly under 6 millimeters. Many users state it is far superior to any shorter focal length ocular of equivalent magnification.

The Barlow sells for $16.00 postpaid, and the Erfle for $14.75 postpaid. Both are guaranteed to perform as stated above or money refunded.

ORTHOSCOPIC OCULARS—All hard coated, standard 1¼-inch outside diameter.

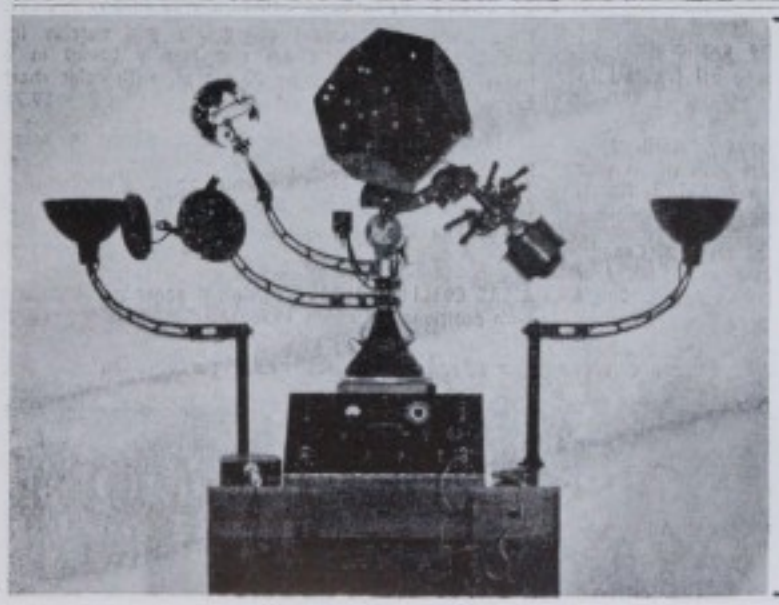
28-mm.	$15.00	10.5-mm.	$16.25	4-mm.	$17.25
16.3-mm. (Erfle)	$14.75	7-mm.	$17.25	Barlow 3x	$16.00

Telescopics
1000 North Seward Street
Los Angeles 38, Calif.

Warranted to equal or surpass any oculars obtainable anywhere or money refunded.

Finished mirrors, mirror kits, spiders, elliptical flats, focusing devices, aluminizing.

Send for catalogue.



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CELESTIAL MECHANICS

E. Finlay-Freundlich. Pergamon Press, New York, 1958. 150 pages. $7.50.

"CELESTIAL MECHANICS still remains the unshakeable foundation on which rests all our knowledge concerning the motion of celestial bodies; and with the advance of astronomy beyond the solar system, new problems are arising which cannot be attacked or solved without its aid. As an instance we can mention the problem of motion of close binary systems on which so much of our astrophysical knowledge is based; and here the light thrown by purely dynamical considerations upon, for example, the problem of distribution of density in the interior of the individual components of a binary shows the usefulness of celestial mechanics for modern astrophysics."

These words quoted from E. Finlay-Freundlich's preface indicate the purpose of his textbook. While earlier books such as F. R. Moulton's *Introduction to Celestial Mechanics* were almost entirely confined to solar system problems, here general methods of dealing with perturbations are presented mainly with stellar applications in mind. Thus the most important chapter is the fifth, which treats motion in a close binary system consisting of nonspherical stars. Relativistic effects are considered, and there is a short discussion of stellar orbits in globular clusters.

In only 150 pages there is little space for the explanation of numerical applications, and many important topics such as the moon's motion are very briefly passed by. For these reasons, as well as the slightness of the introductory chapter, Professor Finlay-Freundlich's book is intended more for the graduate student who is already familiar with the subject than as a general reference work. J. A.

NEW BOOKS RECEIVED

HANDBOOK FOR OBSERVING THE SATELLITES, *N. E. Howard*, 1958, *Crowell*. 136 pages. $2.50.

Amateur observers who wish to see, photograph, or track artificial satellites optically will find extensive instructions in Mr. Howard's book. There is a long account of Operation Moonwatch and its methods, as well as a section on the usefulness of satellites.

PLANET EARTH, *Karl Stumpff*, 1959, *University of Michigan Press*. 191 pages. $5.00.

A prominent German astronomer and geophysicist presents a popular account of the earth as a planet: its motions, physical nature, and role as an abode of life. This is a translation by Philip Wayne of a book first published in Germany in 1955.

THEORY OF RELATIVITY, *W. Pauli*, 1958, *Pergamon*. 241 pages. $6.00.

One of the classic technical expositions of relativity theory is the late Wolfgang Pauli's article in the fifth volume of the German *Encyclopedia of the Mathematical Sciences*. It is now available in English translation as this book. Providing a systematic summary with abridged proofs of all the main developments up to 1921, it has 26 pages of supplementary notes on later work. The treatment is entirely mathematical.

AIRSPACED OBJECTIVES

MOUNTED IN ALUMINUM CELLS f/15

We offer the lowest priced, hand-corrected, precision, American-made astronomical objective, *mounted in a black-anodized aluminum cell.* Our reputation has been established over the years as the most reliable source of high quality astronomical lenses.

"Those in the know" BUY FROM US BECAUSE:

Each lens is thoroughly tested by us and is guaranteed to resolve two seconds of arc or better. They are corrected for the C and F lines (secondary chromatic aberration). The zonal spherical aberration and the chromatic variation of spherical aberration are negligible. The cell is machined to close tolerances so that it will fit directly over our standard aluminum tubing, eliminating any mounting problems.

3¼" diam., 48" F.L. (uncoated) **$28.00**
Same as above with coating **$32.00**

4⅛" diam., 62" F.L. (uncoated) **$60.00**
Same as above with coating **$69.00**

We can supply ALUMINUM TUBING for the lenses above.

"BIG" ACHROMATIC TELESCOPE OBJECTIVES

We have the largest selection of diameters and focal lengths in the United States available for immediate delivery. These are perfect magnesium-fluoride coated and cemented Gov't. surplus lenses made of finest crown and flint optical glass. Not mounted. Fully corrected. Tremendous resolving power. They can readily be used with eyepieces of only ¼" focal length, thereby producing high powers. Guaranteed well suited for astronomical telescopes, spotting scopes, and other instruments. Gov't. cost up to $100.

Diameter	Focal Length	Each	Diameter	Focal Length	Each
54 mm. (2⅛")	254 mm. (10")	$12.50	83 mm. (3¼")	660 mm. (26")	$28.00
54 mm. (2⅛")	300 mm. (11.8")	12.50	83 mm. (3¼")	711 mm. (28")	28.00
54 mm. (2⅛")	330 mm. (13")	12.50	83 mm. (3¼")	762 mm. (30")	28.00
54 mm. (2⅛")	390 mm. (15.4")	9.75	83 mm. (3¼")	876 mm. (34½")	28.00
54 mm. (2⅛")	508 mm. (20")	12.50	83 mm. (3¼")	1016 mm. (40")	30.00
54 mm. (2⅛") *	600 mm. (23½")	12.50	102 mm. (4")	876 mm. (34½")	60.00
54 mm. (2⅛")	762 mm. (30")	12.50	108 mm. (4¼")	914 mm. (36")	60.00
54 mm. (2⅛")	1016 mm. (40")	12.50	110 mm. (4⅜") *	1069 mm. (42-1/16")	60.00
54 mm. (2⅛")	1270 mm. (50")	12.50	110 mm. (4⅜")	1069 mm. (42-1/16")	67.00
78 mm. (3-1/16")	381 mm. (15")	21.00	128 mm. (5-1/16") *	628 mm. (24¾")	75.00
80 mm. (3⅛")	495 mm. (19½")	28.00	128 mm. (5-1/16")	628 mm. (24¾")	85.00
81 mm. (3-3/16")	622 mm. (24½")	22.50	*Not coated		

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COATED BINOCULARS

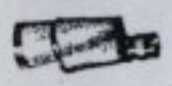
American Type

"Zeiss" Type

Beautiful imported binoculars, precision made, at a low, low price. Above we have pictured the two most popular types. The American Type offers a superior one-piece frame and a clean design, pleasing to the eye. Complete with carrying case and straps. **Price plus 10% Federal tax.**

Size	Field at 1,000 yards	Type	Center Focus	Ind. Focus
6 x 15	360 ft.	Opera	—	$12.75
6 x 30	395	"Zeiss"	$18.75	16.75
7 x 35	341	"Zeiss"	20.75	17.95
7 x 35	341	American	23.50	—
7 x 35	578	American Wide Angle 11°	35.00	—
7 x 50	372	"Zeiss"	24.95	22.50
7 x 50	372	American	32.50	—
8 x 30	393	"Zeiss"	21.00	18.25
10 x 50	275	"Zeiss"	28.75	26.75
20 x 50	183	"Zeiss"	33.75	31.75

MONOCULARS



Brand new, coated optics, complete with pigskin case and neck straps.

	Price		Price
6 x 30	$10.00	7 x 50	$14.75
8 x 30	11.25	16 x 50	17.50
7 x 35	12.50	20 x 50	20.00

"MILLIONS" of Lenses, etc. Free Catalogue

We pay the POSTAGE — C.O.D.'s you pay postage. Satisfaction guaranteed or money refunded if merchandise returned within 30 days.

NEW! 6" LENSES

Our 6" objective will not need high-pressure salesmanship. Its sparkling performance speaks for itself. Test one, or have any qualified person test it; we are certain that you will be satisfied. If not, take advantage of our money-back guarantee.

6" DIAM. AIR-SPACED TELESCOPE OBJECTIVE

Hard coated on 4 surfaces

f/10 - 60" focal length { MOUNTED ..... $175.00 / UNMOUNTED .. 150.00

f/15 - 90" focal length { MOUNTED ..... 175.00 / UNMOUNTED .. 150.00

We can supply ALUMINUM TUBING for the lenses above.

"GIANT" WIDE-ANGLE EYEPIECES

ERFLE EYEPIECE (65° field) contains 3 coated achromats. 1½" E.F.L., clear aperture 2⅛". Has a focusing mount with diopter scale. Will make an excellent 35-mm. Kodachrome Viewer. Magnifies seven times ..... **$12.50 ppd.**

Same as above without diopter scale **$9.95**

WIDE-ANGLE ERFLE (68° field) **EYEPIECE.** Brand new; coated 1¼" E.F.L. Focusing mount. 3 perfect achromats, 1-13/16" aperture **$13.50**

WIDE-ANGLE ERFLE 1½" E.F.L. Brand new; contains Eastman Kodak's rare-earth glasses; aperture 2"; focusing mounts; 65° field **$12.50**

1¼" Diam. Adapter for Erfle eyepieces **$3.95**

SPECIAL COATED OBJECTIVE
BIG 2⅛" DIAM. — 40" F.L. — $6.00

These achromatic objective lenses are tested and have the same high quality as "Big Lenses" described at left, except they are seconds for slight edge chips or small scratches only. Quality guaranteed.

ONLY $6.00 ppd.

ASTRONOMICAL MIRRORS

These mirrors are of the highest quality, polished to ¼-wave accuracy. They are aluminized, and have a silicon-monoxide protective coating. You will be pleased with their performance.

	Diam.	F.L.	Postpaid
Plate Glass	3-3/16"	42"	$ 9.75
Pyrex	4¼"	45"	13.50
Pyrex	6"	60"	25.00

MIRROR MOUNTS, RACK-AND-PINION ● EYEPIECE MOUNTS, and ALUMINUM ● TUBING are available.

90° RIGHT-ANGLE PRISMS

8-mm. face	$1.00		
12-mm. face	1.00		
23-mm. face	1.25	Silvered	$2.00
28-mm. face	1.75	Silvered	2.50
38-mm. face	2.00	Silvered	2.75
48-mm. face	3.00	Silvered	4.00
62-mm. face, coated	$17.50		

TELEVISION PROJECTION LENS

Brand New, f/1.9, E.F.L. 5 inches. Manufactured by Bausch & Lomb. We purchased entire lot of these discontinued units. Five elements, smallest lens 2", largest 4⅛". Completely assembled 6" in length. All surfaces hard coated. Get this BARGAIN now.

ONLY $22.50

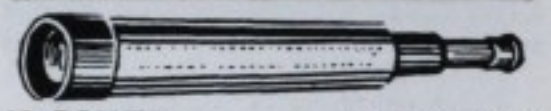
MOUNTED EYEPIECES

The buy of a lifetime at a great saving. Perfect war-surplus lenses set in black-anodized standard aluminum 1¼" O.D. mounts.

F.L.	TYPE	PRICE
6 mm. (¼")	Ramsden	$ 4.75
12.5 mm. (½")	Ramsden	4.50
12.5 mm. (½")	Symmetrical	6.00
16 mm. (⅝")	Erfle (wide-angle)	12.50
16 mm. (⅝")	Triplet	12.50
18 mm. (¾")	Symmetrical	6.00
22 mm. (27/32")	Kellner	6.00
27 mm. (1-1/16")	Kellner	4.50
32 mm. (1¼")	Orthoscopic	12.50
35 mm. (1⅜")	Symmetrical	8.00
55 mm. (2-3/16")	Kellner	6.00
56 mm. (2¼")	Symmetrical	6.00

COATED LENSES 75 cents extra.

GIANT "3" inch TELESCOPE



40 POWER postpaid **$57.50**

HIGH-POWER SPOTTING SCOPE — American Made. Big 3"-diameter achromatic coated objective will give bright crystal-clear images. Micrometer spiral focusing drawtube. Lightweight aluminum construction throughout, black crackle finish, length open 22", closed 15½". Upright image. Guaranteed to give superb performance.

8-POWER ELBOW TELESCOPE

This M-17 telescope has a brilliant-image 48° apparent field — 325 feet at 1,000 yards. The telescope can be adjusted for focusing 15 feet to infinity. It has a 2" objective, focusing eyepiece 28-mm. focal length with an Amici erecting system. Turret-mounted filters: clear, red, amber, and neutral. Lamp housing to illuminate reticle for nighttime use. Truly the biggest bargain you were ever offered. Original Gov't. cost $200.

8 x 50

BARGAIN PRICE .... **$13.50 ppd.**

A. JAEGERS

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Take Pictures Through Your Telescope with the EDMUND CAMERA HOLDER for TELESCOPES

Bracket attaches permanently to your reflecting or refracting telescope. Removable rod with adjustable bracket holds your camera over scope's eyepiece and you're ready to take exciting pictures of the moon. You can also take terrestrial telephoto shots of distant objects. Opens up new fields of picture taking!

SUN PROJECTION SCREEN INCLUDED

White metal screen is easily attached to holder and placed behind eyepiece. Point scope at sun, move screen to focus . . . and you can see sunspots!

All for the low, low price of $9.95

Includes brackets, 28¾" rod, projection screen, screws, and directions. Aluminum . . . brackets black crinkle painted.

Stock #70,162-Y.....$9.95 ppd.

Send check or money order — Money-back guarantee.

ASTRO COMPASS and STAR FINDER

Gov't. Cost $75 — Price $14.95 ppd.

Determines positions of stars quickly. Shows various celestial co-ordinates. An extremely useful star finder which can be rotated through 60° angles along calibrated degree scale. Has single eye lens with viewing stop, two spirit levels for aligning, tangent screw with scale for five precision readings, azimuth scale graduated in two-degree intervals, adjustable tilting azimuth scale for angle reference of stars on distant objects. War surplus. Gov't. cost $75. Instructions, carrying case included.

Stock #70,200-Y.....Only $14.95 ppd.

"TIME IN ASTRONOMY" BOOKLET

By Sam Brown. All about various kinds of time, contains sidereal timetable. How to use single- and double-index setting circles, how to adjust an equatorial mount, list of sky objects. Also includes 7" paper setting circles and stripes suitable for cutting out and mounting on plywood. Wonderfully illustrated.

Stock #9054-Y.....60c ppd.

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Stock #9056-Y.....15c ppd.

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3-inch Astronomical Reflector

60 to 160 Power
An Unusual Buy!

Assembled — ready to use! See Saturn's rings, the planet Mars, huge craters on the moon, star clusters, moons of Jupiter, double stars, nebulae, and galaxies! Equatorial-type mounting with locks on both axes. Aluminized and over-coated 3"-diameter f/10 primary mirror, ventilated cell. Telescope comes equipped with a 60X eyepiece and a mounted Barlow lens, giving you 60 to 160 power. A finder telescope, always so essential, included. Sturdy, hardwood, portable tripod.

Free with scope: Valuable STAR CHART and 272-page ASTRONOMY BOOK.

Stock #85,050-Y.....$29.95 ppd.

TELESCOPE CAMERA

Here is a special camera for taking excellent closeup shots through your telescope — pictures of the moon, stars . . . terrestrial telephoto pictures. Sturdily built, easily operated, this useful camera employs sheet film. One filmholder, size 2¼" x 3¼", is included. Camera lens is 4-element — not only magnifies the image but extends it from normal eyepiece image plane to film plane. Yellow filter included. Camera box size is 3" x 4" x 5". Tube that fits into eyepiece holder is 5" long with 1¼" O.D. for standard telescopes. Cable release and 3¼" x 4¼" piece of ground glass for focusing also included. Precision German-made shutter has settings for Time, Bulb, 1, ½, 1/5, 1/10, 1/25, 1/100, and 1/200 second. Also has delayed-action shutter release.

Stock #70,166-Y.....$39.50 ppd.

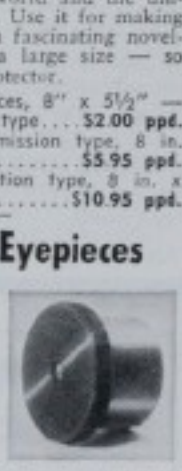
REPLICA GRATING
Low, Low Cost
Take Unusual Color Photos at Night!

It's here — after decades of effort! Replica grating — on film — at very low price. Breaks up white light into full spectrum colors. An exciting display. 13,400 lines per inch. Spectrographs have been used to answer more questions about the structure of the material world and the universe than any other single device. Use it for making spectroscopes, for experiments, as a fascinating novelty. First time available in such a large size — so cheaply. Comes in clear plastic protector.

Stock #50,202-Y....Includes 2 pieces, 8" x 5½" — 1 transmission type, 1 reflection type....**$2.00 ppd.**
Stock #50,180-Y....1 piece, transmission type, 8 in. x 6 ft.....**$5.95 ppd.**
Stock #50,203-Y....1 piece, reflection type, 8 in. x 6 ft.....**$10.95 ppd.**

Mounted Ramsden Eyepieces

Standard 1¼" Diameter



Our economy model, standard-size (1¼" O.D.) eyepiece. We mounted two excellent quality plano-convex lenses in black anodized aluminum barrels instead of chrome-plated brass to save you money. The clear image you get with these will surprise you. Directions for using short focal length eyepieces are included with both the ¼" and ½" models.

Stock #30,204-Y....¼" focal length....$4.75 ppd.
Stock #30,203-Y....½" focal length....$4.50 ppd.

UNMOUNTED HERSCHEL WEDGE

Stock #30,265-Y.....$3.50 ppd.

MOUNTED HERSCHEL WEDGE

Stock #30,266-Y.....$5.50 ppd.

War-Surplus American-Made 7 x 50 BINOCULARS

Big saving! Brand new! Crystal-clear viewing — 7 power. Every optical element is coated. An excellent night glass — the size recommended for artificial satellite viewing. Individual eye focus. Exit pupil is 7 mm. Approximate field at 1,000 yards is 376 feet. Carrying case included. American 7 x 50's normally cost $195. Our war-surplus price saves you real money.

Stock #1533-Y .....$55.00 ppd. (Tax Included)

5" DIAM. TELESCOPE OBJECTIVE AIR-SPACED ACHROMAT

Coated 4 surfaces. Focal length 71", f/14.2. Effective aperture 4.75", f/15.

Stock #70,163-Y...Unmounted.....**$125.00 ppd.**
Stock #70,164-Y...Mounted in cell (inside diam. 5"; outside diam. 5½" with 6½" flange) with adapter to fit 6⅞" I.D. tubing.....**$150.00 ppd.**

DE LUXE FINDER TELESCOPE

Here is a de luxe finder that is very impressive. The telescope part is our regular 5.5-power Moonwatch satellite scope with crosshairs added. The exceptionally large 12° field plus its excellent light-gathering power make this an excellent finder telescope. In addition, you can always take it off for satellite viewing. Twin-ring finder mount is included and makes it easy to center the scope. Can be mounted on tubes of various sizes.

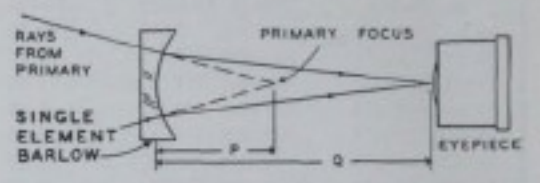
Stock #70,175-Y.....$32.50 ppd.

AERIAL CAMERA LENS
f/2.5 with 7" Focal Length

An excellent lens — can be adapted for use on 35-mm. and Speed Graphic cameras as a telephoto lens. Three of the first four pictures of Sputnik III were taken by a student with a homemade camera using one of these lenses. Adjustable diaphragm, f/16 to f/2.5. Gov't. cost over $400. War surplus.

Stock #70,161-Y.....$39.95 ppd.

DOUBLE AND TRIPLE YOUR TELESCOPE'S POWER WITH A BARLOW LENS



WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to short focal length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power. The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q.

Beautiful chrome mount. We now have our Barlow lens mounted in chrome-plated brass tubing with special spacer rings that enable you to vary easily the power by sliding split rings out one end and placing them in other end. Comes to you ready to use. Just slide our mounted lens into your 1¼" I.D. tubing, then slide your 1¼" O.D. eyepieces into our chrome-plated tubing. Two pieces provided, one for regular focal length eyepieces and one for short focal length ones.

Stock #30,200-Y Mounted Barlow lens.....$8.00 ppd.

"MAKE-YOUR-OWN" 4¼" MIRROR KIT

The same fine mirror as used in our telescopes, polished and aluminized, lenses for eyepieces, and diagonal. No metal parts.

Stock #50,074-Y.....$16.25 ppd.

WAR-SURPLUS TELESCOPE EYEPIECE

Mounted Kellner Eyepiece, Type 3. 2 achromats, focal length 28 mm., eye relief 22 mm. An extension added, O.D. 1¼", standard for most types of telescopes. Gov't. cost $26.50.

Stock #5223-Y.....$7.95 ppd.

EDMUND SCIENTIFIC CO.

SALE! Terrific WAR-SURPLUS BARGAIN! Made by B. & L. and E. K.

These lenses are being successfully used for wide aperture Moonwatch telescopes to see the small and fainter satellites. For eyepiece — use our GIANT ERFLE shown at right.

AERIAL CAMERA LENSES

24" f.l., f/6, in 23"-long lens cone

Gov't. Cost $1218
Our Price, $39.50
Used; $59.50 New

Mounted in beautiful brass cells, lenses are 4"-diam. precision 4-element type, Aero Tessar and Aero Ektar. Housed in cone — focal plane 10" beyond cone and permits building on a filmholder, eyepiece, etc. Lenses are easily removed for other uses. Diaphragm included — adjusts by flexible rod (easily extended) from f/6 to f/22. Opens approx. 1" to 3½". Lens and cone weigh 25 lbs. Sturdy carrying trunk weighs 26 lbs.

USES: 1. For long-range, Big Bertha telephoto lens. 2. For rich-field (wide-field, low-power) telescope. 3. As opaque projector lens. 4. In Operation Phototrack (photographing artificial satellites).

Stock #85,059-Y.....**24", used**.....**$39.50** f.o.b. Utah

Stock #85,060-Y.....**24", new**.....**$59.50** f.o.b. Utah

Send check or money order — Money-back guarantee.

8" SETTING-CIRCLE SET

Two 8"-diam. dials accurately printed on 1/16"-thick black plastic, rigid and unbreakable. White figures on black background. Alternate black-and-white blocks designate divisions, allow easier reading — less eyestrain. ¼" pivot hole in center. Declination circle has 360° divided into 1° intervals, and reads from 0 to 90 to 0 to 90 to 0. Right-ascension circle has 24-hour scale divided into 5-minute blocks with two different scales on the same side. One reads from 0 to 6 to 0 to 6 to 0 hours and the other 1 to 24 hours consecutively. Instruction sheet included.

Stock #50,133-Y....Complete set.....**$3.00 ppd.**

Stock #60,078-Y....360° declination circle only **$1.60 ppd.**

Stock #60,079-Y....24-hour right-ascension circle only **$1.60 ppd.**

5¾" SETTING-CIRCLE SET

Same as described above but with 5¾"-diam. dials.

Stock #50,190-Y....Complete set.....**$2.50 ppd.**

Stock #60,080-Y....360° declination circle only **$1.35 ppd.**

Stock #60,081-Y....24-hour right-ascension circle only **$1.35 ppd.**

EQUATORIAL MOUNT and TRIPOD with CLOCK DRIVE

Heavy-duty mount. Drive operates on 110-volt, 60-cycle, a.c. house current. Follows motion of stars smoothly. 32" tripod legs included.

Stock #85,081-Y.....**$76.50** f.o.b. Barrington, N. J.

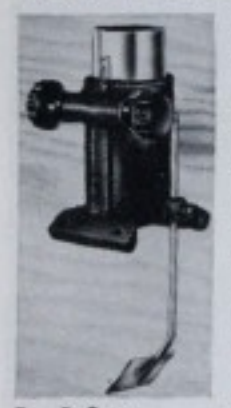
Same mount as above, without clock drive, for 8" or smaller reflectors and for 4" or smaller refractors.

Stock #85,023-Y.....New Low Price.....**$39.50** f.o.b. Barrington, N. J.

MOTORIZED CLOCK DRIVE (by itself) easily attached to your own mount. Instructions included.

Stock #50,198-Y.....**$36.95 ppd.**

Rack & Pinion Eyepiece Mounts



Real rack-and-pinion focusing with variable tension adjustment; tube accommodates standard 1¼" eyepieces and accessory equipment; lightweight aluminum body casting (not cast iron); focusing tube and rack of chrome-plated brass; body finished in black wrinkle paint. No. 50,077-Y is for reflecting telescopes, has focus travel of over 2", and is made to fit any diameter or type tubing by attaching through small holes in the base. Nos. 50,103-Y and 50,108-Y are for refractors and have focus travel of over 4". Will fit our 2⅜" I.D. and our 3⅜" I.D. aluminum tubes respectively.

For Reflectors

Stock #50,077-Y (less diagonal holder) **$8.50 ppd.**
Stock #60,049-Y (diagonal holder only) **1.00 ppd.**

For Refractors

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Stock #70,173-Y.....**$13.50 ppd.**

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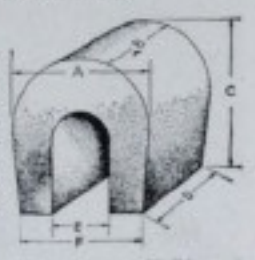

War surplus — Alnico V type. Horseshoe shape. Tremendous lifting power. 5 lb. size. Its dimensions: A — 3¼"; B — 2⅜"; C — 4-5/16"; D — 1¼"; E — 1¼"; F — 2⅛". Strength is about 2,000 Gauss. Will lift over 125 lbs.

Stock #70,183-Y.....**$8.50 ppd.**

15¾-lb. size magnet. Approximately 5,000-6,000-Gauss rating. Will lift over 250 lbs.

Stock #85,088-Y ..... **$22.50** f.o.b. Barrington, N. J.
Shipping wt. 22 lbs.

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Here is an economical plastic slide-focus eyepiece holder for 1¼" O.D. eyepieces. Unit includes 3"-long chrome-plated tube into which your eyepiece fits for focusing. Diagonal holder in illustration is extra and is not included.

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Stock #50,080-Y Finder alone, less ring mounts...**$9.95**

Stock #50,075-Y Ring mounts per pair.....**$3.95**

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GLEANINGS FOR ATM's

CONDUCTED BY ROBERT E. COX

A Large Amateur Observatory of Unusual Design

OBSERVATORIES located close to ground level suffer from heating by conduction and radiation losses that produce air currents which can seriously impair seeing conditions. Therefore, it seems to me that to reduce such effects to a minimum a telescope of moderate size should be mounted high above the ground. This is the first principle that guided me in designing the observatory shown here.

Next, I wanted to include several instruments under one housing, and at present in the 19' dome there are six telescopes carried on two heavy mountings, with their piers resting on concrete ground supports. With such an arrangement, it is obvious that the usual observatory slit would restrict the observing, so the dome was split in two parts, one fitting within the other to provide a view of half of the sky at one time. One of my present instruments, the famous 6-inch Clark refractor with which S. W. Burnham discovered hundreds of double stars, was for many years housed in a dome of this type at the University of Wisconsin.

A flight of stairs leads from the garden beneath Jerome J. Knuijt's elevated observatory to a trapdoor in the observing platform. The latter is supported by four "corner" posts, which also carry the circular wall and dome tracks. With one part of the dome turned within the other, half of the sky is accessible. Five of six main instruments may be seen: left to right, 10-inch reflector, Burnham 6-inch refractor, 12½-inch reflector, and 12-inch reflector carrying a 4-inch refractor. All photographs with this article provided by the author.

The floor of my observatory is 15′ above the ground, with the dome top 27′ high. This elevation of the telescopes has greatly improved the quality of the seeing, as tests on difficult double stars have shown. At present I am completing an observing project to compare the visual performance of two pairs of instruments: a 4-inch Clark refractor and a 4-inch reflector, Burnham's 6-inch and a 6-inch reflector. Upon completion, this will have required several hundred hours of observing over a span of one calendar year.

This rather complete and versatile observatory is a far cry from the first telescope I tried to make when my interest in astronomy began 10 years ago, after graduating from high school. A three-dollar lens proved of little value for astronomical observing, and almost spoiled stargazing for me until optics books at the library put me on the right track.

Sometime later I became acquainted with a well-known local amateur astronomer and telescope maker, Carl Elias. He has been constructing instruments since the early 1920's, and he sold me an 8-inch reflector and mounting. Then, with his assistance, I made another 8-inch Newtonian, and together we completed a 12-inch reflector only four days before my induction into the U. S. Army in 1953.

While in the service I visited several large observatories on the West Coast, as well as the Tacoma and Yakima astronomy clubs in Washington. I made another 12-inch mirror in the workshop of the Tacoma group, mounting it on a wooden stick as a tubeless telescope and observing with it on an abandoned airstrip at Ft. Lewis. My spare time was used for drawing plans for an observatory incorporating the principles described above.

Upon my return home early in 1955, my father helped me build the observatory on his property, and it was completed after six months of intensive labor. The entire construction was done with common tools: hammers, pliers, saws, wrenches, and the like.

At this stage in the construction of the observatory, the floor joists were in place and the tongue-and-groove flooring was about to be installed. The top section of one of the two instrument piers is visible.

The footings for the observatory supports and telescope piers are set deep below the frost line, and the forms were tapered out to give better anchorage in the ground. The final forms on which the piers sit were carefully leveled, and no other leveling was necessary as we proceeded with construction.

Bolts securing the observatory-support pipes to the footings are 4′ pieces of $\frac{5}{8}$″ steel rod, their lower ends bent sharply to insure catching firmly in the concrete. These bolts were positioned by hanging them from a board with four holes corresponding to those in the pipe flange. Heavier steel rods were used for the 500-pound pipe of each of the 10′ telescope piers.

Although the observatory is circular, the framework at the top of the piers is square, as shown in the picture. The main beams are held by corner angle plates of right-angle iron $\frac{5}{8}$″ thick with sides 4″ wide and $1\frac{1}{2}$′ long. The floor joists are spaced so the telescope piers come into the observing room between two of them. The trapdoor was set in such a position that the stairs would clear the bottoms of the telescope piers. The 2-by-10″

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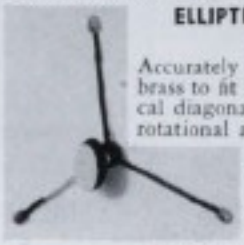

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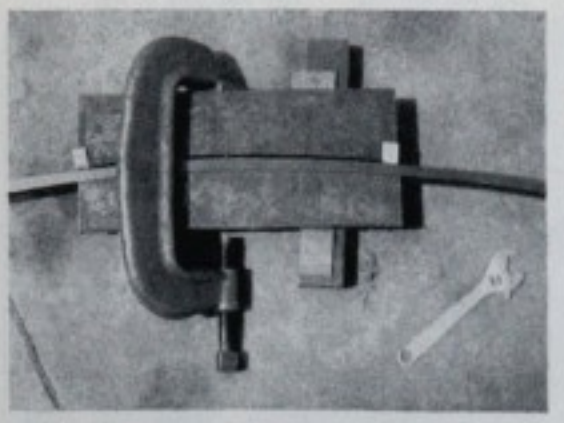


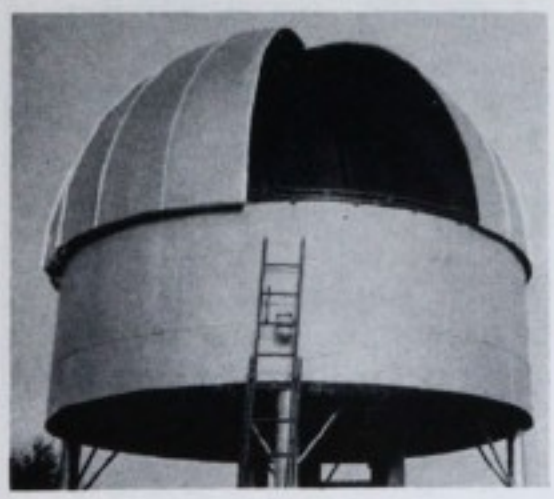
Mr. Knuijt used this rig to shape steel strips for the dome braces. When the C-clamp was released, the strip assumed a nine-foot radius.

joists carry 1″ tongue-and-groove flooring.

Along the outer edge of the flooring are pieces of 2″ plank cut to a 9′ radius, forming a solid base to which the 2-by-4's for the side walls are nailed. On top of the side wall is a ring of 3/16″ steel plate 8″ wide that carries the rollers for the inner and outer dome sections.

This ring was fabricated from individual sections about 5′ long, riveted together. The accompanying picture shows the method of bending the dome tracks and the dome braces. A piece of 1″ steel plate was cut along a 6′ radius line, the resulting two pieces being clamped over the iron to be bent. Bolts 5′ long secure the ring to the top of the side wall and tie the whole wall to the floor joists.

Malleable aluminum sheets 1/32″ thick were used to form gores for the dome, each section being 3′ wide and 16′ long. The sheets were joined by a double-turned standing seam such as described on pages 497-498 of *Amateur Telescope Making — Book Two*. The gores were riveted to the dome braces and dome track carrier plates. There is a stainless steel plate at the apex of each dome half to which the ends of the aluminum sheets are riveted, and a 3″ spacer separates the outer and inner domes and provides a central pivot at the zenith. Live rubber strips attached just inside the edges of each half of the dome provide a perfect weather seal. A small



Another view of the completed dome shows it partially opened. The two overlapping sections are each a quarter sphere, often called a semidome. The pattern of aluminum gores forming them is easily seen.

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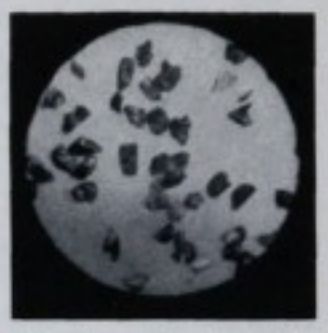

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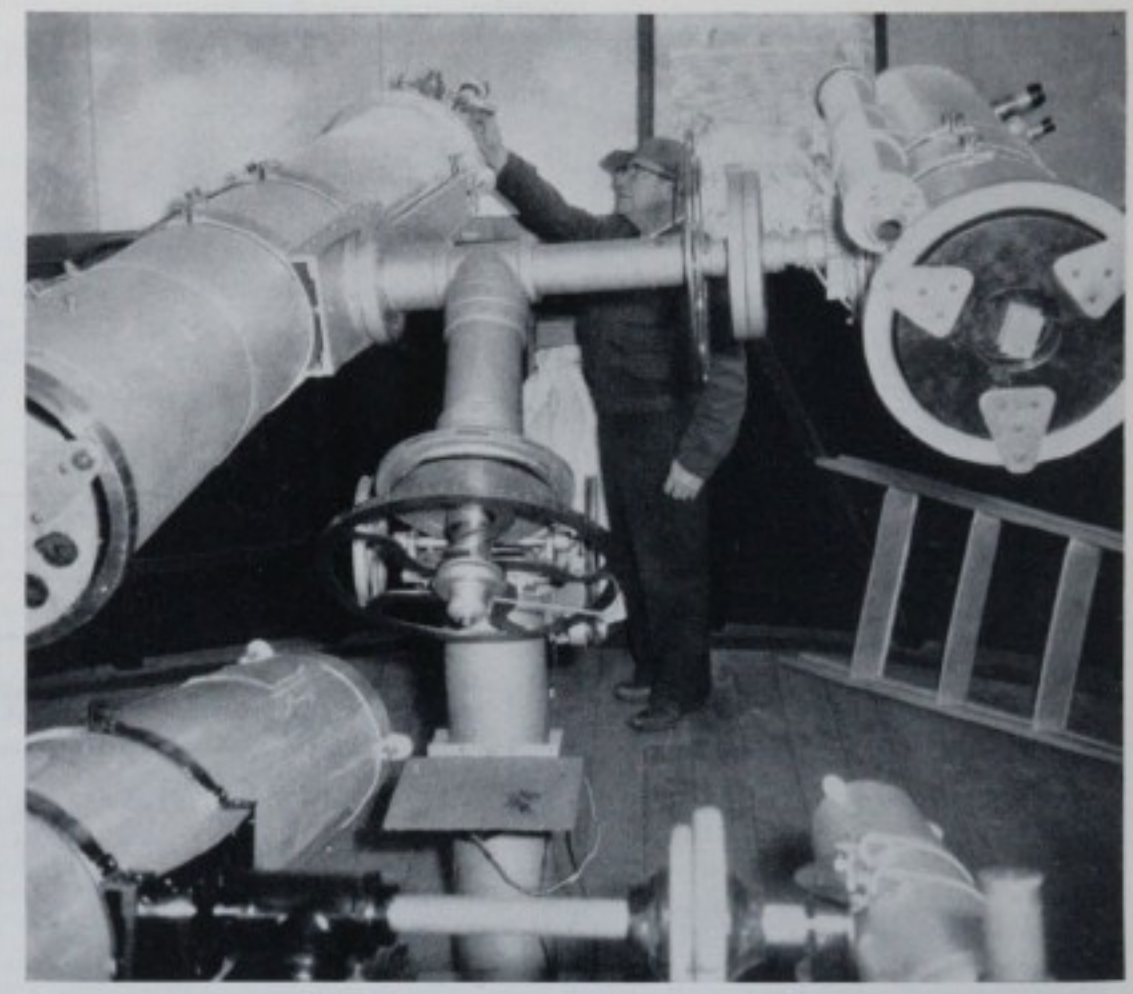

Visiting the Knuijt observatory, a neighbor, Mr. Brusch, is seen here at the eyepiece end of the 12½-inch reflector, which carries piggyback the 6-inch Burnham refractor. The latter is on loan from Washburn Observatory, but is not seen here, as it is on the far (left) side of the 12½-inch tube. Counterbalancing this combination are another pair (upper right), a 12-inch reflector carrying a 4-inch refractor. In the lower foreground is the declination axle of the second mounting, carrying at the left a 10-inch reflector and at the right counterweights and a 4-inch telescope.

latch lock can be secured when the dome is closed, preventing a strong wind from causing the halves to separate.

When the halves are fully opened nearly half of the sky is visible at one time. No dome drive is needed, and it is possible to observe for hours without shifting the dome position.

There are six telescopes in the observatory, all in operating condition: 4- and 6-inch refractors, 4½-, 10-, 12- and 12½-inch reflectors. Two of the smaller telescopes provide some of the counterweighting required for the 10-inch and 12½-inch reflectors, and they were made with short focal lengths so they would not strike the piers when the main instruments were shifted from one side of the polar axis to the other.

A year after completion of the construction work, I went to the Washburn Observatory to see Burnham's 6-inch refractor, but learned that this fine instrument had been put in storage to make room for a 12-inch Cassegrainian reflector being used with photoelectric equipment. At the suggestion of Dr. A. E. Whitford, then director at Washburn, the Burnham instrument was lent to me by the university's extension division. It is mounted on the 12-inch reflector and I treat it as carefully as if it were my own. The new director, Dr. A. D. Code, is permitting me to use Burnham's instrument until the latter part of this year. This is one of four telescopes being compared in the observing program mentioned earlier.

Since its erection, over 700 persons have visited my observatory, and many groups have come for an evening of star study (see front cover). Amateurs visiting in this area are invited to come at any time. Among the visitors have been Dr. Whitford, who is now director of Lick Observatory, a high-school exchange student from Austria, and a Mexican college student.

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The most important part of a reflector telescope is the precisely figured mirror. A mirror with a spherical surface suffers from spherical aberration, so it must be altered to a paraboloid to focus all the light rays in each bundle to the same point. Considerable skill is required to parabolize a fine mirror properly. Criterion Custom mirrors are made of the best pyrex glass, selected for freedom from internal stress and strain, and of the correct thickness for each size, parabolized by craftsmen and tested by Ronchi and Foucault tests, as well as by diffraction rings and resolution of double stars. They are aluminized and overlaid with zircon quartz. Each is guaranteed unconditionally, and to perform to the limit of resolution for its size.

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Cat. #SU-38 **$7.95 postpaid**

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Diagonal Rod Cat. #SU-9R $1.00

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S-51	1.25"	6½" to 7½"	$10.00
S-52	1.30"	6½" to 7½"	10.00
S-53	1.50"	8½" to 9½"	10.00
S-54	1.75"	9½" to 10½"	12.50
S-55	2.00"	11" to 11½"	14.95
S-56	2.50"	Specify tube I.D.	19.95

Revolving Turret

The Criterion Revolving Turret holds three eyepieces so that, as desired, the power of the telescope can be changed by merely turning the turret to a different ocular. Click stop insures positive and accurate positioning of each eyepiece. Turret holds eyepieces of standard 1¼" outside diameter. Fits into the holder of any refractor or reflector telescope that uses 1¼" eyepieces. Requires no alteration or adjustment and can be attached as easily as putting eyepiece into scope. Made of brass and aluminum with polished chrome-plated barrels.

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MAY METEORS

The moon, almost new, will not interfere with observations of the Eta Aquarid meteor shower, which reaches maximum on the morning of May 5th this year. At the peak of this 10-day shower, a single observer may see about 12 meteors per hour under good sky conditions. On the date of maximum the radiant will be at right ascension $22^h\ 24^m$, declination 0°, and moving northeastward by about a degree per day. W. H. G.

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CELESTIAL CALENDAR

Universal time (UT) is used unless otherwise noted.

ALGOL OBSERVATIONS

New determinations of the times of Algol minima are always desirable, in order to trace the changing period of this famous eclipsing variable star. During the minimum of February 26-27, 1959, I observed the brightness of Algol photoelectrically with my 8-inch reflector, using a 1P21 photomultiplier tube behind a Corning 3384 yellow filter. Between 7:17 and 11:07 p.m., Central standard time, 27 comparisons were made with the neighboring star Pi Persei. Sky conditions were not ideal, as occasionally there were light clouds.

From a plot of these observations, the time of minimum was found by the tracing-paper method (described on pages 190-192 of the February, 1957, issue) to have been 9:34 p.m., which is 20 minutes later than predicted in SKY AND TELESCOPE. The corresponding heliocentric Julian date is 2,436,626.647.

DONALD ENGELKEMEIR
732 S. Thurlow St.
Hinsdale, Ill.

MINIMA OF ALGOL

May 1, 5:16; 4, 2:05; 6, 22:54; 9, 19:43; 12, 16:32; 15, 13:20; 18, 10:09; 21, 6:58; 24, 3:47; 27, 0:36; 29, 21:25.

June 1, 18:14; 4, 15:02; 7, 11:51.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

MOON PHASES AND DISTANCE

New moon	May 7, 20:11
First quarter	May 15, 20:09
Full moon	May 22, 12:56
Last quarter	May 29, 8:13
New moon	June 6, 11:53

	May	Distance	Diameter
Apogee	8, 4^h	252,600 mi.	29′ 23″
Perigee	22, 5^h	221,900 mi.	33′ 27″

JUPITER'S SATELLITES

The configurations of Jupiter's four bright moons are shown below, as seen in an astronomical or inverting telescope, with north at the bottom and east at the right. In the upper part, *d* is the point of disappearance of the satellite in Jupiter's shadow; *r* is the point of reappearance.

In the lower section, the moons have the positions shown for the Universal time given. The motion of each satellite is from the dot toward the number designating it. Transits over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from *The American Ephemeris and Nautical Almanac*.

MAY

Phases of the Eclipses of the Satellites

Configurations at 0h 00m

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. To obtain daylight saving time subtract 4, 5, 6, or 7 hours, respectively. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th, and to 10:15 p.m. PST on the 14th.

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12½″ CAVE ASTROLA de luxe, professionally equipped with electric slow motions and the like (see Cave ad, *Sky and Telescope*, page 181, February, 1957). 13½′-diameter dome, marine plywood, clean modern design, built-in Newtonian platform, remote-control electric drive. Scope and dome in excellent condition. Package price $2,500.00. Robert Neville, 3637 Serra Rd., Malibu, Calif.

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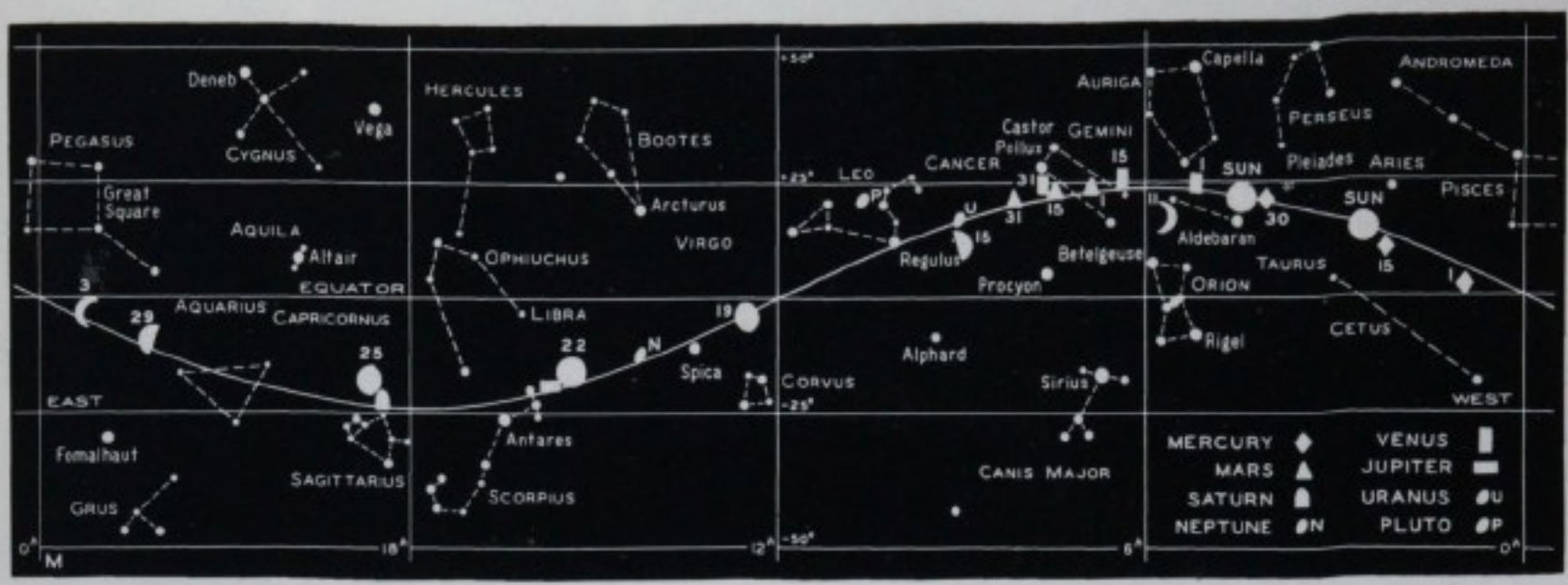

THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other days shown. All positions are for 0^h Universal time on the respective dates.

Mercury is in the morning sky all month, but too near the sun to be found without difficulty.

Venus is in Gemini in mid-May, and can be seen in the west as a brilliant object of magnitude −3.6, setting about 3½ hours after the sun. Telescopically, the planet has a gibbous disk 68-per-cent illuminated and 16″.5 in diameter.

Mars moves eastward from central Gemini into Cancer during May. In mid-month the reddish planet is magnitude +1.7, and well past the meridian at sundown; it sets shortly before midnight, local time. In a telescope the disk is only 4″.7 in diameter.

Jupiter reaches opposition on May 18th, 406 million miles from the earth. On this date it rises about sunset and can be seen the rest of the night as a very bright object, magnitude −2.1, in eastern Libra. Even a very small telescope will show Jupiter's flattened disk, 42″ in polar diameter and 45″ in equatorial. The nearly full moon will pass about 2½° north of Jupiter on the night of May 21-22.

Saturn on the 15th is of magnitude +0.5, in Sagittarius, rising in the southeast about three hours after sunset. Telescopically, its disk is 16″ in diameter and the extent of the ring system is 40″.

Uranus reaches eastern quadrature on May 3rd, then crossing the meridian about sunset. It is in Cancer, a 6th-magnitude object visible with slight optical aid during the early evening. Its position on the 3rd is right ascension 8^h 59^m.3, declination +17° 47′ (1950 co-ordinates).

Neptune, an 8th-magnitude object in eastern Virgo, can be seen in binoculars and small telescopes. It is in the southeast after sunset, its position on the 15th being 14^h 18^m.2, −11° 28′ (1950). W. H. G.

OCCULTATION PREDICTIONS

May 12-13 **Lambda Geminorum** 3.6, 7:15.6 +16-37.0, 5. Im: **A** 0:18.8 −1.1 −1.2 87; **B** 0:14.2 −1.2 −1.0 80; **C** 0:18.5 −1.1 −1.5 101.

May 15-16 **Pi Leonis** 4.9, 9:58.0 +8-14.5, 8. Im: **H** 4:28.4 . . . . . 56.

For stations in the United States and Canada, usually for stars of magnitude 5.0 or brighter, data from the *American Ephemeris* and the *British Nautical Almanac* are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard-station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo,** lat. **L**) within 200 or 300 miles of a standard station (long. **LoS,** lat. **LS**). Multiply **a** by the difference in longitude (**Lo**−**LoS**), and multiply **b** by the difference in latitude (**L**−**LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

A	+72°.5,	+42°.5	**E**	+91°.0,	+40°.0
B	+73°.6,	+45°.5	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	Discontinued	
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
			I	+123°.1,	+49°.5

CORRECTION

Bruce Blackadar, State College, Pennsylvania, points out that the Greek letters δ and ζ marking stars in the Belt of Orion should be interchanged in the evening star chart on page 357 of the April issue of this magazine.

MINOR PLANET PREDICTIONS

Amherstia, 516, 9.3. May 12, 17:14.2 −47-23; 22, 17:07.1 −47-56. June 1, 16:57.0 −47-52; 11, 16:46.0 −47-08; 21, 16:36.9 −45-49. July 1, 16:30.9 −44-07. Opposition on June 6.

Metis, 9, 9.5. May 22, 17:54.0 −24-43. June 1, 17:45.6 −25-03; 11, 17:35.3 −25-18; 21, 17:24.4 −25-31. July 1, 17:14.3 −25-38; 11, 17:05.6 −25-41. Opposition on June 15.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

VARIABLE STAR MAXIMA

May 4, R Reticuli, 043263, 7.7; 8, T Aquarii, 204405, 7.9; 11, R Bootis, 143227, 7.3; 12, R Octantis, 055686, 7.9; 15, R Leonis, 094211, 5.9; 19, R Ophiuchi, 170215, 7.6; 19, U Orionis, 054920a, 6.6; 21, RS Scorpii, 164844, 6.8; 23, S Coronae Borealis, 151731, 7.5; 30, V Cassiopeiae, 230759, 7.9; 31, U Cygni, 201647, 7.6.

June 5, S Carinae, 100661, 5.7; 6, T Centauri, 133633, 6.1.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

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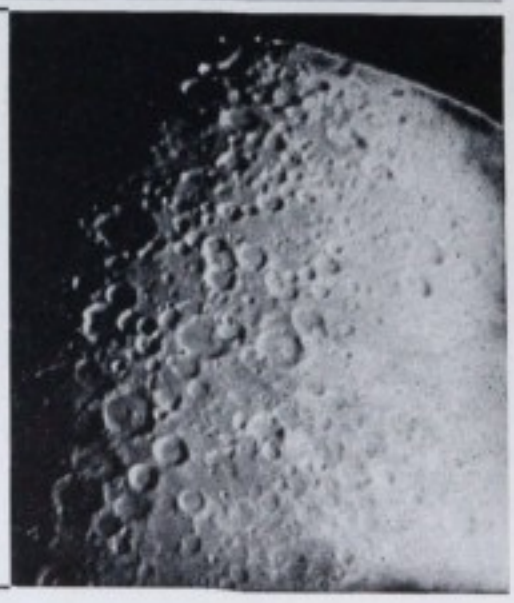

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Please rush to me at no cost or obligation a copy of the new UNITRON Catalog of Astronomical Telescopes including the Observers Guide 20-Q.

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Be Certain of Optical Excellence – Choose UNITRON

MANY Models To Choose From!

2" SATELLITE ($7.50 Down) 6x, diagonal eyepiece, altazimuth mount with circles, stand — **$75**

1.6" ALTAZIMUTH ($7.50 Down) with eyepieces for 78x, 56x, 39x — **$75**

2.4" ALTAZIMUTH ($12.50 Down) with eyepieces for 100x, 72x, 50x, 35x — **$125**

2.4" EQUATORIAL ($22.50 Down) with eyepieces for 129x, 100x, 72x, 50x, 35x — **$225**

3" ALTAZIMUTH ($26.50 Down) with eyepieces for 171x, 131x, 96x, 67x, 48x — **$265**

3" EQUATORIAL ($43.50 Down) with eyepieces for 200x, 131x, 96x, 67x, 48x — **$435**

3" PHOTO-EQUATORIAL ($55.00 Down) with eyepieces for 200x, 171x, 131x, 96x, 67x, 48x — **$550**

4" ALTAZIMUTH ($46.50 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x — **$465**

4" EQUATORIAL ($78.50 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x — **$785**

4" PHOTO-EQUATORIAL ($89.00 Down) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x — **$890**

4" EQUATORIAL with clock drive **($98.50 Down)**, Model 160V, eyepieces as above — **$985**

4" EQUATORIAL with clock drive and metal pier **($107.50 Down)**, Model 166V, eyepieces as above — **$1075**

4" PHOTO-EQUATORIAL with clock drive and Astro-camera **($117.50 Down)**, with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x — **$1175**

4" PHOTO-EQUATORIAL with clock drive, pier, Astro-camera **($128.00 Down)**, eyepieces for 375x, 300x, 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x — **$1280**

6" EQUATORIAL with clock drive, pier, 2.4" view finder, with eyepieces for 625x, 500x, 416x, 357x, 277x, 200x, 138x, 100x, 62x, 42x — **$5125**

6" PHOTO-EQUATORIAL as above but with 4" guide telescope, illuminated diagonal, UNIBALANCE, Astro-camera Model 330 — **$5660**

6" PHOTO-EQUATORIAL as above with addition of 3" Astrographic Camera Model 80 — **$6075**

Use Our EASY PAYMENT PLAN

UNITRON's popular Easy Payment Plan is a convenient and economical way to buy your UNITRON Refractor when you do not want to disturb your savings or when you haven't the total cost of the telescope immediately available. The down payment required is 10%. The balance due is payable over a 12-month period, and there is a 6% carrying charge on the unpaid balance. Your first payment is not due until 30 days after you receive the instrument, and if you should want to pay the entire balance due at that time, the carrying charge is canceled. (6" models available on special plan.)

There is no "red tape" when you order — you merely fill in the UNITRON Easy Payment Order Form, return it together with the required down payment, and the model of your choice is shipped to you at once.

Do not hesitate to use this plan merely because you have never before purchased anything on time payments. The procedure is practically painless and is an ideal means of enjoying the use of your UNITRON while paying for it.

HOW TO ORDER

Send check or money order in full or use our Easy Payment Plan, as described above. Shipments made express collect. Send 20% deposit for C.O.D. shipment. UNITRON instruments are fully guaranteed for quality, workmanship, and performance, and must meet with your approval or your money back.

There is much to recommend a UNITRON Refractor as the logical choice for the amateur astronomer. A UNITRON, optically speaking, duplicates the performance of larger telescopes of other types. With its long focal length, higher magnifications of planetary and lunar images are obtained with low-power eyepieces. Moreover, there are no mirrored surfaces to become oxidized, no components which require periodic alignment, no secondary optics to cause diffraction patterns, and no folding of the light back on itself through turbulent air with consequent loss of definition. No wonder that you see more and see better with a UNITRON — the telescope that has withstood the test of time.

Note These UNITRON Features

- LENSES are FULLY CORRECTED for spherical and chromatic aberration and are COATED for maximum brilliance and clarity of image. Optics especially designed for astronomical observation. AIR-SPACED OBJECTIVES.
- REFRACTOR type of design duplicates the performance of larger telescopes of other types. No mirrored surfaces to become oxidized. Superior definition to the very edge of the field.
- EYEPIECES of the HIGHEST QUALITY: Orthoscopic, Achromatized Symmetrical, Kellner, Huygens. Three to ten eyepieces included with each instrument.
- FINEST MATERIALS used throughout. DURALUMIN TUBE. Moving parts of BRASS carefully machined to close tolerances, and finished in CHROMIUM. No war-surplus components used.
- MODERN DESIGN based on time-tested engineering principles. HANDSOME APPEARANCE to which no illustration can do justice.
- EQUATORIAL MODELS have slow-motion controls for **both** declination and right ascension as well as rapid-motion controls. Sturdy TRIPOD (or PIER).
- ALTAZIMUTH MODELS have slow-motion controls for **both** altitude and azimuth as well as clamps for both co-ordinates. Sturdy TRIPOD.
- VIEW FINDER with crosshair eyepiece.
- RACK-AND-PINION FOCUSING.
- Choice of UNIHEX Rotary, Eyepiece Selector or STAR DIAGONAL and ERECTING PRISM for TERRESTRIAL OBSERVATION. The same complete range of terrestrial magnifications as for celestial observation.
- SUNGLASS for solar observation.

Higher- and lower-power eyepieces available for all models. Prices include basic accessories, tripod and mounting, fitted wooden cabinets, and operating instructions. Additional accessories available to add further to your observing pleasure.

UNITRON's Popular VIEW FINDERS

1. (As used on UNITRON 2.4" Models): 23.5-mm. (.93") achromatic objective, 6x eyepiece with crosshairs. Chromed brass tube. Mounting brackets with centering screws.

Only $8.50 postpaid

2. (As used on UNITRON 3" Refractors): 30-mm. (1.2") coated achromatic objective and 8x eyepiece with crosshairs. Other details as in View Finder 3.

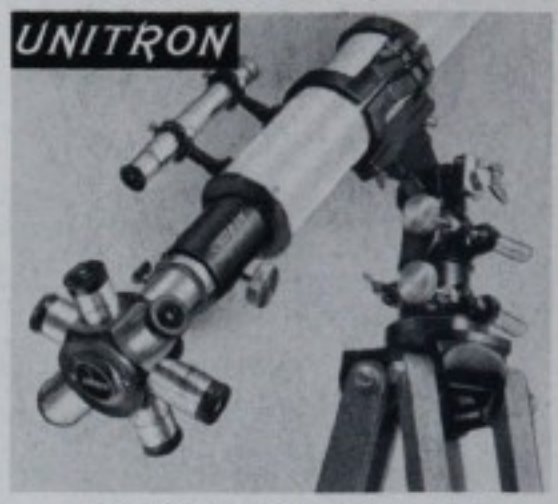
Only $10.75 postpaid

3. (As used on UNITRON 4" Refractors): 42-mm. (1.6") coated achromatic air-spaced objective. 10x eyepiece with crosshairs. Duralumin tube finished in white enamel. Dewcap. Furnished with mounting brackets, centering screws for collimation, and mounting screws. This finder measures approximately 16" over-all. It is light in weight, compact and small enough for use as a hand telescope furnishing spectacular wide-field views of the sky.

Only $18.00 postpaid

See the back cover.

Consider These Favorites



UNITRON 2.4" Altazimuth

America's most popular low-priced refractor

UNITRON 6" Photo-Equatorial

the logical choice for the serious observer and for the school and college observatory

UNITRON SATELLITE TELESCOPE

for the critical observer who wants the very best

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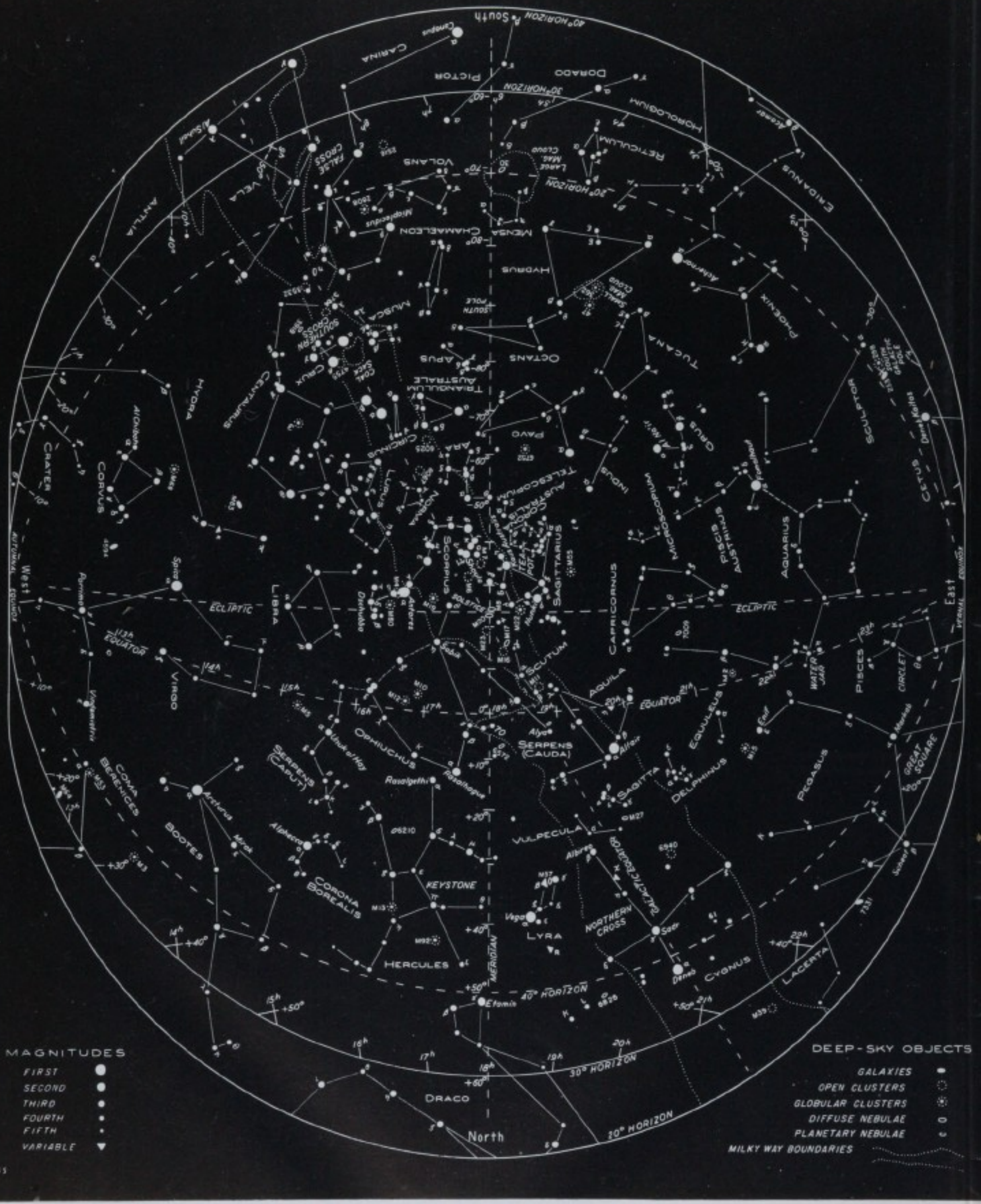

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SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south, at 11 p.m. and 10 p.m., local time, on the 8th and 23rd of July, respectively; also, at 9 p.m. and 8 p.m. on August 7th and 22nd. For other dates, add or subtract ½ hour per week.

When facing south, hold "South" at the bottom; turn the chart correspondingly for other directions. The equator, ecliptic, galactic equator, and meridian are dashed lines; the horizon is shown for locations 20°, 30°, and 40° south of the earth's equator, respectively.

©

STARS FOR MAY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 8th and 23rd of May, respectively. For other dates, add or subtract ½ hour per week.

The Big Dipper is on the meridian in early evening, marking the middle of spring in the Northern Hemisphere. Follow the arc of the handle to orange Arcturus, the 1st-magnitude star in Bootes. Note two famed small constellations in the southern sky: Crater the Cup and Corvus the Crow.

GOTO
TOKYO

GOTO'S MEDIUM-SIZE PLANETARIUM

Established in 1926, Japan's oldest and largest firm specializing in astronomical telescopes.

Goto Optical Mfg. Co., Japan's foremost maker of astronomical telescopes, is nearing completion of its revolutionary medium-size planetarium.

FEATURES :

1. Projects the entire celestial sphere and can show the sky above any point in the world. Therefore, the starry sky above various points south of the equator, particularly the Antarctic, can also be projected to the very last detail.
2. Projection of the annual motions of the moon, sun and five planets is possible. In other words, the peculiar movements of the planets can be shown.
3. Precession phenomena can be projected.
4. Automatic explanations can be given with tape recorder.
5. Music and imitation sounds can be played by an inserted record player.
6. Remote control from the control desk is possible.
7. By using auxiliary projection apparatus various different types of performances and projection are possible.

We are erecting a special building to give actual demonstrations with this medium-size planetarium at the Tokyo International Trade Fair, May 5 — 22, 1959.

Catalogues will be sent upon request.

GOTO OPTICAL MFG. CO.
1-115 Shimmachi, Setagaya-ku, Tokyo, Japan

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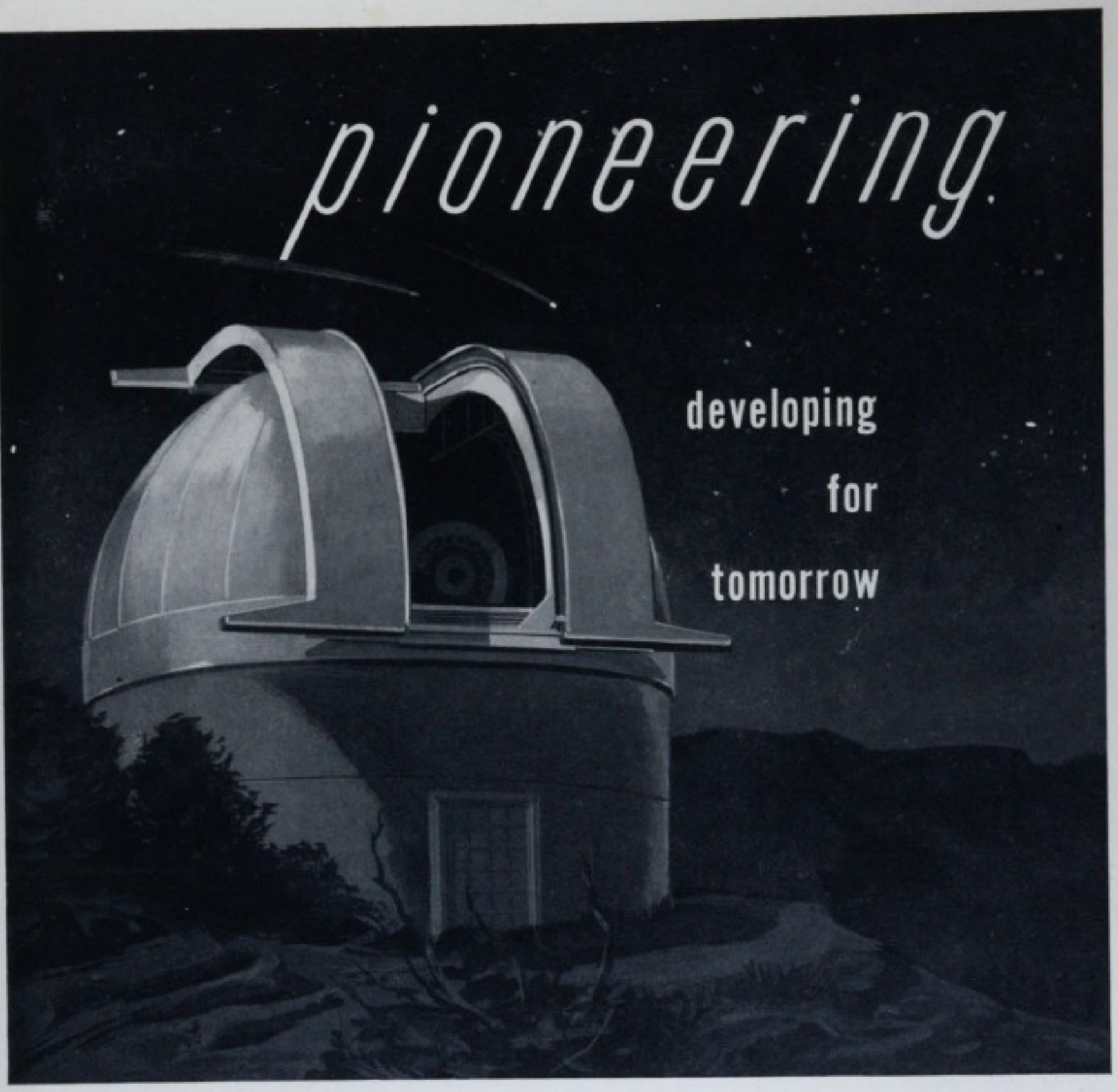
GOTOPTIC TOKYO



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Experience has shown that it usually takes from one to five years to plan and complete an observatory project. If you are interested in preparing your educational facilities to meet the rising demands of the space age, now is the time to begin your basic studies, and to find out how an ASTRO-DOME can play an important part in your future. Our trained staff will be glad to aid you in determining the type of dome to fit your requirements.

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This 4" UNITRON is yours for only $128 down

You can tell at a glance that here is a telescope designed to achieve professional results. Indeed, this 4" UNITRON has been chosen for important research by university observatories, the U. S. and foreign governments, and leading industrial laboratories. Ownership of such a superb instrument might be thought to be beyond the means of many amateur astronomers, yet a 10% down payment of only $128 puts you at the controls of this magnificent UNITRON.

The full purchase price of $1280 includes everything the serious observer wants and needs to make the most of his observing — clock drive, fixed pier, Astro-Camera, 2.4" photographic guide telescope, Super-UNIHEX, large 42-mm. 10x view finder, eyepieces, and a complete selection of accessories in addition to these pictured above.

With this 4" UNITRON, you have at your disposal a complete range of magnifications: 25x, 38x, 60x, 83x, 120x, 167x, 214x, 250x, 300x, 375x. And, with the Super-UNIHEX Rotary Eyepiece Selector, you can switch from a spectacular wide-field view of the sky to high-power observation of planetary details at a flick of a finger.

There are other UNITRON 4" models for as little as $465 complete ($46 down) and other UNITRON Refractors for as low as $75 ($7.50 down). All may be purchased using our Easy Payment Plan. Whichever model you choose, you are assured of obtaining the finest instrument in its class. After all, it is a UNITRON.

See pages 414 and 415.

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